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CONTENTS

November 1956

Editorials and Annotations		Page
Induced Hypotension	*D. I. Chisholm and R. R. Macintosh, Oxford*	791
Clinical Studies		
Fractures of the Odontoid Process of the Axis	*N. J. Blockey, Glasgow, and D. W. Purser, Manchester*	794
Stress Fractures of the Fibula	*M. B. Devas, Hastings, and R. Sweetnam, London*	818
Post-irradiation Fractures of the Neck of the Femur	*W. H. Stephenson, London, and B. Cohen, Johannesburg*	830
Induced Hypotension in Orthopaedic Surgery	*Frank Holmes, Edinburgh*	846
Tuberculoma of Striated Muscle	*Evan Griffiths, Bridgend*	855
Ankle and Subtalar Fusion by a Transarticular Graft	*A. C. Bingold, London*	862
Extraskeletal Osteochondromata	*D. W. Purser, Manchester*	871
Calcification of Articular Cartilage	*Henry Bunjé, Kingston-on-Thames, and W. R. Cole, Jamaica*	874
Myelography in the Lumbar Region with Water-soluble Contrast Medium	*Th. Boesman, Leiden*	882
Paraplegia due to Hydatid Disease	*T. J. Mills, London*	884
A Metastasising Adamantinoma of the Tibia	*A. D. Morgan and D. H. Mackenzie, London*	892
Unreduced Traumatic Dislocation of the Hip	*I. K. Mikhail, Dhahran*	899
Pathology and Basic Sciences		
The Prehensile Movements of the Human Hand	*J. R. Napier, London*	902
Histological Changes in Experimentally Displaced Upper Femoral Epiphyses in Rabbits	*W. Robert Harris and K. W. Hobson, Toronto*	914
The Arterial Supply to the Adult Cervical Vertebral Bodies	*R. S. Harris and D. M. Jones, Bristol*	922
The Blood Supply of Developing Long Bones with Special Reference to the Metaphyses	*O. J. Lewis, London*	928
Proceedings and Reports of Universities, Colleges, Councils and Associations		
Great Britain, Italy, New Zealand		934
Book Reviews		954
Index to Volume		965
Contributors' Addresses		976

The Journal of
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EDITORIALS AND ANNOTATIONS

INDUCED HYPOTENSION

Orthopaedic surgeons have for a longer time than others been familiar with the attractions of working in a bloodless field, as much of their operative surgery is performed on the limbs, where a tourniquet may be used with satisfaction and safety provided the well-established principles relating to choice, application and duration of application of the tourniquet are observed. In recent years thought has been directed towards providing similar operating conditions in other parts of the body, a matter of interest not only in orthopaedics but in almost every branch of surgery. For this to be achieved a state of hypotension is deliberately induced in the patient.

Prolonged clinical experience shows that the reasonably fit patient can support even an unrecordable blood pressure throughout a surgical operation, provided the brain is not above heart level and the blood is well oxygenated. During the latter part of his distinguished surgical career Koster employed only spinal analgesia even for operations above the clavicle, and never gave a vasopresser drug to counteract the almost inevitable fall in blood pressure. Long ago he pointed out (1928) the incidental advantages of the bloodless operation field. A good head of pressure is essential if the erect posture is to be maintained, but a surprisingly low one will drive blood round the horizontal patient. Kidney and liver function are presumably much diminished during the period of hypotension, but, provided the parenchyma is kept well oxygenated, these organs are soon capable of re-establishing the *milieu interieur*.

To-day hypotension is most commonly achieved by the use of drugs that block the sympathetic ganglia and so cause arteriolar dilation. Of these, hexamethonium is the one whose use is described in this issue of the Journal by Dr Frank Holmes, of the Edinburgh School, which has contributed so much to our knowledge of this subject. We must not lose sight of the fact that the amount of bleeding can often be considerably reduced by quite simple means. Venous congestion is obviously to be avoided. The anaesthetist plays his part here by making sure that there is no resistance in the circuit of his apparatus, and by maintaining an impeccable airway. Venous drainage of the tissues may be improved by paying attention to the position of the patient, particularly for example in operations on or near the vertebral column as described by Taylor, Gleadhill, Bilsland and Murray (1956). A combination of these principles with local infiltration with adrenalin, and perhaps premedication with chlorpromazine, is often sufficient. It is improbable that the method of arteriotomy (Hale 1948) is practised now, but the hypotensive effect of spinal analgesia, particularly the high spinal block of Griffiths and Gillies (1948), can be as profound and as successful as that achieved in any other way.

Whatever the means whereby hypotension is induced, there are three people chiefly concerned in the result: the patient, the surgeon and the anaesthetist, and the matter should be examined from the standpoint of each.

The patient will derive certain important benefits. He will lose less blood. This desirable feature is enhanced by the corollary that he will less frequently require a blood transfusion, with its potential risks. This may be especially important if he is of an unusual blood group, when blood for transfusion may not be readily available. He can expect a better final result from his operation, notably in the field of plastic surgery, for not only is the surgeon able to

carry out delicate procedures more expertly and more expeditiously in a field that is dry, but he will also use less ligatures, with the prospect of better cosmetic results. Less anaesthetic is required: not only is the operating time reduced, but once the patient is settled at a systolic blood pressure of say 60–70 millimetres Hg, less anaesthetic agent is required to keep him at the desired plane. Finally, he may be able with reasonable safety to undergo a vascular operation that might not have been technically possible without making him deliberately hypotensive.

On the other hand, the patient is exposed to certain additional risks of which the gravest during operation are those associated with hypoxia and thrombus formation, and the possible effects of these on brain and heart readily spring to mind. If the operation is above the patient's clavicles, and there is almost no oozing from cut surfaces, then there is likely to be a marked reduction of blood flow through the brain: the threat to tissue respiration is obvious. Effects of cerebral hypoxia are not always gross, as references to articles such as those of Bedford (1955) and Argent and Cope (1956) will show. Even without hypotensive techniques these include greater or lesser degrees of personality change, and cerebral oedema. If, in addition to a poor current, the vessels are atheromatous, two important elements of thrombus formation are present. The same arguments apply to the coronary circulation where myocardial infarction or damage from thrombus formation or sub-oxygenation are possible. Cardiac output, depending in considerable measure on the position of the patient, may be reduced. If the arterial blood pressure is greatly lowered, with the blood pooling in the widely dilated arterial side of the circulation in the most dependent part of the body, the *vis a tergo* for venous return to the heart is lost; and if the blood is not returned to the heart, it cannot be put out again. Any shifting of the patient, any tilting of the operating table, therefore, must be performed slowly, as little as is necessary, and with knowledge of the likely effect. It cannot be stressed too strongly that any rise of the head above the level of the heart threatens the cerebral circulation.

Towards the end of the operation, the patient is exposed to two further hazards. Firstly, haemorrhage may occur as the blood pressure rises, either because the hypotensive agent is discontinued or because a vasopressor drug like methylamphetamine is used. This complication is less likely to arise when the choice of agent is arfonad, because a fairly rapid rise of pressure is usually seen when it is stopped, while the patient is still on the table. Secondly, until the blood pressure has returned to its normal level, the patient is not in full possession of his protective reflexes. Skilled and informed nursing is essential once he has left the theatre; rapid and pronounced movement of the patient must be avoided, and a perfect airway is imperative.

There is no absolute certainty that the patient has come through his operation unscathed until it is apparent that his mental faculties are unimpaired and the danger of embolism is past.

It follows that use of the technique should not be entertained in patients with a history of myocardial infarction or coronary insufficiency, in patients with any bar to efficient transport of oxygen to the tissues, such as chronic pulmonary disease, anaemia, recent heavy blood loss, shock, or arteriosclerosis. Nor must it be undertaken lightly in those who show hypertension: though the need here is great, the risk, too, is increased.

It is the lot of the anaesthetist to induce hypotension; hence his work and responsibilities are greatly increased. He is wise not to undertake a case single-handed. If he uses a ganglion-blocking agent, he has more preparations to make, he must induce and maintain anaesthesia flawlessly, he must constantly ensure that the respiratory excursion and oxygenation are adequate, he must keep a frequent regular check on the blood pressure and adjust the administration of the hypotensive agent accordingly. If despite hypotension there is even a moderate loss of blood, perhaps unexpectedly, he must be prepared to make it good promptly because the patient's physiological responses to ensure carriage of oxygen to the tissues are in abeyance. He must endeavour to bring the blood pressure to its normal level by the end

of the operation, and preferably to have the patient awake. He may have to keep the patient under his personal care in the recovery room for longer than usual, and must always ensure that arrangements for transport to, and reception in, the ward are satisfactory. If despite the most careful attention the patient suffers any mishap, he will feel keenly responsible. No anaesthetist should ever take the matter lightly nor be persuaded to undertake a case against his better judgment.

The question arises as to how the anaesthetist is to gain skill and experience in the technique. He may read about it, and he may watch others employ it, but, as with all techniques, he does not get the "feel" of it until he has practised it himself. If he is to be ready to employ it when indicated, and he is unlikely to regard himself as a competent anaesthetist unless he can do so, he should be armed by experience gained beforehand, even in cases where hypotension is far from essential. When he should do so and whether he should do so are problems that he must decide for himself, once his theoretical knowledge of the technique, its advantages and dangers, is as complete as possible.

For the surgeon, the benefits during the operation are self-evident. He will find the difficult is made less so, and occasionally the impossible is made possible. It is therefore understandable that his enthusiasm for the method exceeds that of the anaesthetist, although it may be dampened if he is later required to deal with a haematoma caused by reactionary haemorrhage, or if he finds that his patient has become hemiplegic or a dullard. But induced hypotension, in selected cases, has come to stay. These deplorable mishaps are due to errors in technique or judgment. That the misuse of any drug can have grave consequences is common knowledge, and is no valid argument against its proper employment.

In all cases, therefore, the decision whether or not to reduce the blood pressure for an operation should be made by the surgeon and the anaesthetist in consultation. The initiative in suggesting it should come from the surgeon, for he knows the nature of the operation he wishes to perform, but he should not suggest it unless he considers that the benefit to the patient will outweigh the risks. D. I. CHISHOLM and R. R. MACINTOSH.

REFERENCES

ARGENT, D. E., and COPE, D. H. P. (1956): Cerebral Hypoxia: Aetiology and Treatment. British Medical Journal, **i**, 593.

BEDFORD, P. D. (1955): Adverse Cerebral Effects of Anaesthesia on Old People. Lancet, **ii**, 259.

GRIFFITHS, H. W. C., and GILLIES, J. (1948): Thoraco-Lumbar Splanchnicectomy and Sympathectomy: Anaesthetic Procedure. Anaesthesia, **3**, 134.

HALE, D. E. (1948): Controlled Hypotension by Arterial Bleeding during Operation and Anesthesia. Anesthesiology, **9**, 498.

KOSTER, H. (1928): Spinal Anesthesia with Special Reference to its Use in Surgery of the Head, Neck and Thorax. American Journal of Surgery, **N.S. 5**, 554.

TAYLOR, A. R., GLEADHILL, C. A., BILSLAND, W. L., and MURRAY, P. F. (1956): Posture and Anaesthesia for Spinal Operations with Special Reference to Intervertebral Disc Surgery. British Journal of Anaesthesia, **28**, 213.

FRACTURES OF THE ODONTOID PROCESS OF THE AXIS

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and

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The purpose of this paper is to review the literature of fracture of the odontoid process of the axis vertebra, to analyse the anatomical and clinical features of this injury, and to discuss the prognosis in relation to treatment. The analysis will be based upon eleven cases which we ourselves have observed and upon the reported features of forty other cases which are described in sufficient detail by their reporters. We believe that we can show that the natural history of the fracture in children differs from that in adults, that failure of bony union is common and that the dangers of the injury have been exaggerated.

REVIEW OF THE LITERATURE

Association with fracture of the atlas—We have not been able to find the first description of fracture of the odontoid, but there appears to have been a belief that it occurred in association with injuries of the atlas. This belief persisted into the present century, and was supported by Corner (1907) who quoted six fatal cases of rotatory dislocation of the atlas associated with fracture of the odontoid. Again, Jefferson (1927) drew attention to the "frequent" association of fractures of the atlas and of the odontoid. The fact that the odontoid could be broken in the absence of injury of the atlas was, however, suggested in 1912 by Fritzsche and later demonstrated by Wüsthoff (1923), by Magnant (1931) and by Angelesco and Buzoianu (1931).

In the early days of radiology Fritzsche (1912) suggested attempting to demonstrate fractures of the odontoid in a postero-anterior projection by holding a dental film against the posterior pharyngeal wall. This technique was further developed by Plaut (1938) in his study of fractures of the anterior arch of the atlas. Anderson and Burgess (1939) advised the same technique, this time for odontoid fractures. In 1943 Judd recommended an occipito-mental view, in which the odontoid was to be seen framed in the shadow of the margins of the foramen magnum.*

Opinions on the production of the fracture—Most of the reported fractures have resulted from severe violence, particularly falls from considerable heights or injuries in road accidents. Less severe violence has, however, sufficed. Willard and Nicholson (1941) reported a case as a result of a fight between children. Bull (1942) saw the fracture after electric shocks.

Fritzsche was able to fracture an odontoid once in a series of experiments planned to imitate judicial hanging. In this instance the mechanism was one of distraction of the head from the upper cervical vertebrae, and it is not unreasonable to assume that the odontoid process was avulsed by the alar ligaments. These ligaments, which become tight at the extremes of flexion, extension and rotation of the head, are the check ligaments of the occipito-atlanto-axial joints. Any impact on the head, throwing it into any extreme position might, therefore, avulse the odontoid process, the separation occurring at its base, where structurally it is weakest. Kolisko (1916) pointed out that the alar ligaments are tight when the head is flexed, and can therefore contribute to the fracturing of the odontoid process when at impact the head is in flexion.

* None of these techniques has helped us much. The standard lateral cervical and "open-mouth" views outline the fracture very clearly. We used them in our cases.

Wüsthoff (1923) believed that the odontoid is usually fractured by the powerful transverse ligament which passes behind it. He quoted but disbelieved an observer named Smith who had shown that the odontoid process is in fact stronger than that ligament, for Wüsthoff had discovered post-mortem evidence of fractures of the odontoid with intact transverse ligaments.

Anatomy of the odontoid with reference to fractures—There is a rudimentary island of cartilage in the body of the adult axis. This has been known at least since Bardeen described its origin in 1910. It appears to be present in about a quarter of the population between the ages of thirty and fifty (Plaut 1938).

The odontoid process ossifies from two centres, which fuse together soon after they have appeared during the fifth month of intra-uterine life. From these fused centres are developed parts of the superior articular facets and the upper part of the body of the bone. The epiphysial plate which separates these odontoid centres from the ossific centre for the body of the axis, therefore, lies in the main mass of the vertebra (Fig. 1). Up to the age of six years it is a well defined structure. About this time the centres fuse. The circumference of the plate of cartilage diminishes and its height decreases. After the age of seven years a small cartilaginous blemish in the cancellous structure of the body is all that remains.

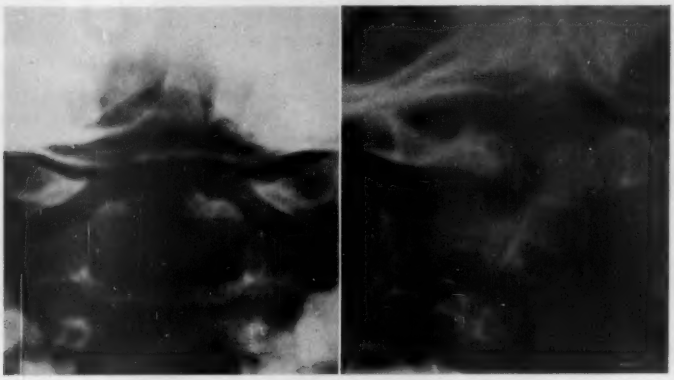

FIG. 1

Antero-posterior and lateral views of the upper cervical spine at the age of four, showing the situation of the epiphysial plate in the body of the axis.

It has been suggested that this island may determine the site of fracture in the adult odontoid (Plaut 1938). We do not agree with this view, but it is interesting that, despite this suggestion, no one seems to have considered that the fracture of the odontoid process seen in young children is in fact an epiphysial separation. (See reports of fractures in children by Mixter and Osgood 1910, Tavernier 1931, Willard and Nicholson 1941 and Hamilton 1951.)

Displacement—It has been known since Fritzsche's study in 1912 that the fractured odontoid might displace forwards or backwards. Wüsthoff (1923) went so far as to try to differentiate clinically between forward and backward displacement. He held that in forward displacement the normal hollow below the occiput was obliterated, whereas in backward displacement it was accentuated. The rarity of backward displacement was pointed out by Reich (1938) and by Tippett (1951), each of whom described one case.

Does bony union occur?—Opinions about the healing of the fracture vary. At the post-mortem examination on Lambotte's (1894) patient, union by fibrous tissue was found. Bernstein (1903) and Pilcher (1910) on the other hand reported the plentiful formation of callus. Fritzsche (1912) stated that bony union was often insufficient, and in his review he found only two cases in which union had occurred. Pseudarthroses found post mortem were reported by Elliott and Sachs (1912), Dürck (1930) and Magnant (1931). Cone and Turner (1937) thought that

bony union was to be expected in most cases if adequate reduction and immobilisation were achieved. Roberts (1937), from a study of five cases, concluded that healing took place slowly. Again, Eastwood (1940) stated that " fibrous union has been reported but is not common in my experience." He did not state upon how many cases this opinion was based.

The rarefaction that occurs at the fracture site in cases of non-union has led to ideas of " secondary osteoporosis of the odontoid " (Lepeuple and Parneix 1937). Schwarz and Wigton (1937) referred to the same change as " fibrosing osteitis " and Heublein (1944) as " rarefying osteitis." Though all these reports suggest that an obscure process must be postulated to explain the rarefaction, we can see no need for this. The changes appear to be identical with those seen in fibrous union in any small bone, and to be the result and not the cause of the non-union.

Paraplegia of late onset—In 1931 Tavernier published radiographs of a fracture of the odontoid process showing progressive subluxation of the atlas. Cone and Turner (1937) named this sequence of events " cervical axial spondylolisthesis." Kahn and Yglesias (1935) illustrated not only this progressive slipping, but in one of their cases, when a considerable deformity was present, demonstrated evidence of compression of the spinal cord. In three of the six fatal cases quoted by Corner (1907) death was the result of a tetraplegia of onset some time

FIG. 2
Age incidence of fractures of the odontoid (fifty-one cases).

after the fracture. Wüsthoff's (1923) patient, whose fracture was initially in good alignment, developed paralysis of arms and legs at the end of six months, by which time a gross deformity was present. Schwarz and Wigton (1937) reported two cases of spastic paraplegia which could only be explained by fractures of the odontoid sustained many years before.

Mixter and Osgood (1910) deduced that a myelitis caused by the irritation of long-continued abnormal position, the trauma of abnormal mobility, or the pressure of callus, accounted for the late onset of neurological disorders. Bernstein (1903) had found the spinal cord compressed by callus. Osgood and Lund (1928) suggested that osteomyelitis might sometimes be a cause of delayed paraplegia after a fracture of the axis. On the other hand Schwarz and Wigton (1937), in whose cases there was little or no displacement, were of the opinion that the neurological manifestations were due to a post-traumatic spinal arachnoiditis in the cervical region.

Prevention of paraplegia—While opinions differed about the cause of paraplegia arising some time after the fracture, there was much support for the suggestion that early spinal fusion might prevent it. Short of actual fusion, Mixter and Osgood (1910) suggested stabilising the upper cervical spine by anchoring the posterior arch of the atlas to the spine of the axis with a silk ligature. Spinal fusion as a prophylaxis against delayed cord signs was advocated by

Tavernier (1931). Kahn and Yglesias (1935) reserved this operation for cases showing evidence of progressive atlanto-axial subluxation, but Cone and Turner (1937) felt that when a fracture of the odontoid process was present, even though undisplaced, the patient was safer if an operation to fuse the upper cervical vertebrae was performed.

MATERIAL PRESENTED IN THIS PAPER

We report eleven new cases of fracture of the odontoid. Their details are given in Table I. Two occurred in children under the age of seven, the rest in adults aged eighteen and over. Nine of these, including the children, have been followed for two years or more.

We are considering the details of these personal cases with those of forty adequately reported previously (Table II). The age incidence of fifty-one cases is shown in Figure 2.

THE INJURY IN CHILDREN UNDER THE AGE OF SEVEN YEARS

We believe that fracture of the odontoid in young children is always an epiphysial separation. There are several reasons for this view. First, there is a difference in the levels at which the axis fractures in the adult and in the young child. The lateral radiographs of our patients show that in the adult the fracture-line usually lies at or above the level of the upper articular facets (Figs. 9 to 12), whereas in the young child the fracture line is well below the facets in the body of the bone (Figs. 3 and 4). Second, in the adult the displaced fragment of the odontoid is shorter than the undisplaced body of the axis; in the infant this is reversed.

In small children a fracture-line cannot be seen on the antero-posterior view. The epiphysial line can be seen quite clearly. In the lateral film, displacement of the odontoid process can be recognised, the fracture-line can be seen, but not the epiphysial line. This is illustrated in Figure 4 in which the displacement of the odontoid and the line of fracture are seen on the lateral radiograph, though on the antero-posterior view taken with the mouth open the only evidence of a fracture is a line running downwards from the left superior articular facet to the central epiphysial line. The shadow across the base of the odontoid process in this film is caused by the anterior arch of the atlas. It is therefore reasonable to assume that the fracture-line lies at the epiphysial plate. Furthermore, the length of the displaced fragment of odontoid process as measured from the lateral radiograph is equal to the measurement of the odontoid on the antero-posterior view, taken from the epiphysial line to the top of the process. These anatomical features are seen also in the radiographs of the patients of Willard and Nicholson (1941), Hamilton (1951) and Winston (1954). Table III summarises the features of the fracture at this age.

Prognosis in young children—Like epiphysial separations in other parts of the body, the separated odontoid in the young child unites readily (Fig. 5). Imperfections of reduction are smoothed off in time. In the two such cases reported here (Cases 10 and 11, Table I) union occurred in seven and thirteen weeks respectively, and at the end of three years the appearances, both clinical and radiological, were normal. Radiographs taken in full flexion and full extension showed a normal range of neck movement (Figs. 6 and 7). The forward displacement of the posterior arch of the atlas, which had not been completely corrected by the initial treatment, was no longer apparent.

THE INJURY IN ADULTS

Reference has already been made to an island of cartilage, the remnant of the epiphysial plate, which is sometimes present in the body of the axis in the adult. If the odontoid fractures, the fracture-line usually bears no relation to this structure (Fig. 11). The bone breaks at the base of the odontoid, and the fracture runs transversely across or obliquely down from the groove which separates the odontoid process from the lateral mass to the inner aspect of the lateral mass on the other side (Figs. 14 to 17). In only two patients, one reported by Roberts (1937) and one by us, has the fracture-line run into the body of the bone in the region of the

TABLE I

ELEVEN CASES OF FRACTURE OF THE ODONTOID

Case number	Age and sex	Violence causing fracture	Associated injuries	Direction of displacement
1 (Mr Griffiths's case)	60 years. Male	Hit by a recoiling hawser on right side of face. Fell backwards, hitting head or neck on a rail	Fracture of mandible	No displacement (Fig. 9)
2 (Mr Charnley's case)	19 years. Male	Cycled into a track attendant. Combined hyperextension and vertical compression	Fracture of atlas	Backward (Fig. 11)
3 (Sir Geoffrey Jefferson's case)	67 years. Male	Knocked down by motor-cycle. Details unknown	Abrasions left side of face, and laceration left side of face	Backward
4 (Mr Charnley's case)	18 years. Female	Cycled into a wall when brakes failed. Combined hyperextension and vertical compression	Unconsciousness. Small depressed fracture left side of skull	Backward
5 (Mr Charnley's case)	22 years. Female	Fell off cycle. Friend ran over back of her neck	Laceration on chin	No displacement
6 (Mr Charnley's case)	23 years. Male	Motor-cycle accident. Details unknown	Abrasion left side of face	Forward
7 (Sir Harry Platt's case)	60 years. Male	Knocked down by car. Details unknown	Abrasion left side of face	No displacement
8 (Mr Griffiths's case)	33 years. Male	Car accident. Thrown forwards. Hit chin on steering wheel	Fracture of mandible bilaterally at level of neck, and through symphysis menti	Forward (Fig. 21)
9 (Mr A. Ronald's case)	45 years. Male	Trapped by machinery. Probably tangetial blow on back of head	Laceration occipito-parietal. Fracture left tibial tuberosity	Backward
10 (Mr Griffiths's case)	4½ years. Female	Fell 20 feet from a bedroom window	Laceration on tip of chin	Forward (Fig. 4)
11 (Mr Griffiths's case)	2¾ years. Female	Knocked down by motor van	Laceration of scalp	Forward (Fig. 3)

NOTES

1. The expression " continuous traction " implies weight traction employing Crutchfield's caliper, with the patient supine in bed with head raised on blocks.
2. " Plaster collar " implies a plaster incorporating the Crutchfield caliper and extending to the iliac crests.

TABLE I—*continued*

Neurological complications		Treatment	Result	
Early	Late			
Dysphagia for 1 year	None	Continuous traction for 6 weeks. Plaster collar for 6 weeks (see footnote)	Non-union.	Last seen 3 years 3 months after injury. In full employment. Occasional ache in the neck and slight limitation of movement. Condition not deteriorating. Slight movement at fracture (Fig. 10) (see footnote)
Severe neck pain. Occipital paraesthesia	None	Continuous traction for 6 weeks. Plaster collar for 6 weeks	Bony union.	Last seen 2 years after injury. Serving in the Royal Air Force. No symptoms or signs (Fig. 12)
None	None	Continuous traction for 3 weeks, then wiring. Leather collar for 9 months. Wire broke	Non-union.	Died 4 years 2 months after injury from coronary thrombosis. Last seen 4 years after injury, when in full employment. Occasional ache in the neck
Right hemiplegia. Left hemianaesthesia. Transient	None	Continuous traction for 6 weeks. Plaster jacket for 6 weeks. Occipito-cervical fusion at 3 months	Bony union.	Last seen 3 years after injury when in full employment. No symptoms. Slight limitation of movement. Radiographic evidence of sound occipito-cervical fusion
None	None	Cardboard collar for 3 months. Plaster collar refused	Non-union.	Last seen 2 years 6 months after injury when in full employment. Spasm and pain on full movement—not worsening (Fig. 13). Slight movement at fracture
None	None	Plaster collar for 4 months	Bony union.	Last seen 2 years after injury when working as a forester. Slight ache on extension of the head. No disability
None	None	Plaster collar for 3 months. Cardboard collar for 2 months	Non-union.	Last seen 3 years after injury when in full employment. Occasional pain on extremes of movement. Slight limitation. Not deteriorating. Slight movement at fracture (Figs. 14 to 17)
Intense occipital neuralgia	None	Traction for 6 weeks. Plaster collar for 6 weeks	Bony union.	Last seen 6 months after injury when in full employment. Slight pain and terminal limitation of movement. Improving (Fig. 23)
Incomplete tetraplegia. Recovered in 3 months	None	Traction for 6 weeks. Plaster collar for 6 weeks	Bony union.	Last seen 4 months after injury. Neck stiff, but no pain. Improving
Extensor plantar responses. Abdominal reflexes absent	None	Continuous traction for 7 weeks	Bony union.	Last seen 3 years 6 months after injury when at school. No symptoms or signs. Remodelling of odontoid (Figs. 5 to 7)
None	None	Continuous traction for 5 weeks. Plaster collar for 8 weeks	Bony union.	Last seen 3 years after injury when at school. No symptoms or signs. Remodelling of odontoid

NOTES—*continued*

3. "Slight movement at fracture" in "Result" column implies that comparison of radiographs taken in full flexion and extension shows slight movement between the odontoid process and the body of the axis vertebra.

TABLE II

FORTY PREVIOUSLY REPORTED CASES OF FRACTURES OF THE ODONTOID

Case number	Source	Age and sex	Violence causing fracture	Associated injuries	Direction of displacement
12	Mixter and Osgood (1910)	15 years. Male	Fall from a tree	None reported	Forward
13	Pilcher (1910)	33 years. Male	Fall 15 feet on to forehead	None	Forward
14	Fritzsche (1912)	47 years. Male	Fall 3½ feet on to soft ground. Head was flexed	None reported	No displacement
15	Wüsthoff (1923)	16 years. Male	Fall on to the back of the head	None	Forward
16	Murphy, quoted by Osgood and Lund (1928)	Adult	Not stated	None	No displacement
17	Ryan (1931)	28 years. Female	Fall off bicycle. Fell forward on to the head	None reported	Forward
18	Tavernier (1931)	11 years. Male	Fall down lift-shaft. Hit back of head	None	Forward
19	Craig (1931)	18 years. Male	Injury when playing football	None	Forward
20	Anderson (1932)	30 years. Male	Fall out of car on to head	None	No displacement
21	Lande and Dervillee (1934)	20 years. Male	Fall from bicycle	Abrasions left side of face. Left brachial plexus palsy	Forward
22	Meyerding (1935)	23 years. Female	Car accident. Struck back of head on roof of car	Abrasions left side of forehead, left side of neck, and cut lip	No displacement
23	Kahn and Yglesias (1935)	18 years. Male	Car accident	Compound fracture of the left parietal. Multiple fractures of the mandible	Forward
24		20 years. Male	Car accident	None	Forward
25	Lepeuple and Parneix (1937)	Young adult. Male	Fall against a wall. Blow on right side of of occiput	None	No displacement
26	Cone and Turner (1937)	42 years. Male	Car accident. Thrown through windscreen	Multiple lacerations of face, fractured ribs, haemothorax	Forward
27		14 years. Male	Fell backwards off a load of hay, striking the back of the head	Comminuted fracture of the anterior arch of the atlas	Backward
28	Roberts (1937)	24 years. Female	Car accident	None	No displacement
29		55 years. Female	Fall down flight of stairs	Injury to hip (not a fracture)	No displacement
30		55 years. Male	Car accident	None	Backward
31		53 years. Male	Fall down flight of stairs	None	Forward
32		33 years. Male	Fall off a truck	Fracture of the lateral mass of the third cervical vertebra, with subluxation of C.3 on C.4	No displacement

TABLE II—*continued*

Neurological Complications		Treatment	Result
Early	Late		
None	Severe occipital neuralgia at 6 months	Two manipulations, then plaster helmet at 6 months. Reduction and internal fixation at 7 months	Non-union
None	Sudden hemiplegia at 3 months	Operation. Exploration only. Plaster at 4 months	Bony union
None	None	None for 4½ weeks, then manipulation	Not reported. Probably non-union
None	Gradual onset of paraplegia at 5 months	None for 6 months, then bed rest and collar	Non-union
None	None	None for 1 month, then plaster	Non-union
None	Onset of tingling in the hands at 3 months	None for 3 months, then reduced and plaster collar worn for 4 months	Non-union
None	None	Traction for 5 months. Minerva plaster for further 3 months, then spinal fusion	Non-union at 8 months. Union after fusion not stated
None	At 9 months monoplegia left arm ataxia	None for 4 weeks. Cervical traction then for 4 months. Laminectomy at 9 months	Non-union
None	None	Minerva plaster. Period not stated	Not reported
None	None	None	Non-union
None	None (at 9 months)	Seventeen days traction to the head. 6 weeks plaster collar	Non-union
None	At 3 months, pain right arm, weakness of abductors of right shoulder, arm reflexes increased, later right hemiplegia	For 3 months no treatment. Head traction with improvement, followed by Forrester collar. Laminectomy and fusion after further deterioration	Non-union
None	None (at 6 months)	No treatment, then permanent Forrester collar	Non-union
None	None	Three months in plaster	Bony union
None	At 16 years, paraesthesiae in hands and leg weakness	Massage, then laminectomy and fusion at 16 years	Non-union
Quadriplegia (Recovered rapidly)	None	Fusion of the cervical spine at 5 days	Bony union
None	None	Three months in Minerva plaster collar. Three months in leather collar	Bony union
None	None (at 5 years)	None	Non-union
None	None	Traction for 1 month. Plaster collar for 2 months	Bony union
None	Incomplete paralysis of the arms and legs at 5 months	None for 5 months. Laminectomy at 5 months	Non-union
Difficulty in swallowing	None	Leather collar for 3 months. Thomas collar for 1 month	Bony union

TABLE II—*continued*

FORTY PREVIOUSLY REPORTED CASES OF FRACTURES OF THE ODONTOID

Case number	Source	Age and sex	Violence causing fracture	Associated injuries	Direction of displacement
33	Schwarz and Wigton (1937)	34 years. Male	Fall from a hayloft at 10 years	Unconscious	Forward
34		53 years. Female	Thrown from a horse, striking back of head on a rock at 48 years	Unconscious	No displacement
35	Reich (1938)	55 years. Female	Car accident. Blow on the forehead	Extensive lacerations of the forehead	Backward
36	Willard and Nicholson (1941)	7½ years. Male	Injured when fighting	None	Backward
37		3½ years. Female	Neck trodden on by an adult	Fracture of right humerus	Forward
38	Rogers (1942)	Adult	Not stated	None reported	Forward
39	Bull (1942)	60 years. Male	Three electrical convulsions	None	Forward
40	Crooks and Birkett (1944)	37 years. Male	Motor-cycle accident	None reported	Backward
41		Adult	Stated to have been severe violence such as fall from a height, or motor-cycle accident	None reported	Forward
42		Adult	Ditto	None reported	Forward
43		Adult	Ditto	None reported	Forward
44	Heublein (1944)	21 years. Male	Fall from a truck	None	Backward
45	Colsen (1949)	Young adult. Male	Manipulation of neck under general anaesthetic	None	Forward
46	Hamilton (1951)	2 years. Female	Road accident	Fractured mandible	Forward
47	Tippett (1951)	58 years. Male	Thrown from horse, landing heavily on the right side of his face	None	Backward
48	Grogono (1954)	17 years. Male	Fall off motor-cycle	None	Forward
49		79 years. Female	Fall downstairs, striking the head	None	Forward
50		69 years. Female	Motor accident. Hyperextension injury	None	Backward
51	Winston (1954)	6½ years. Male	Fall downstairs, striking back of the head	None	Forward

TABLE II—*continued*

Neurological complications		Treatment	Result
Early	Late		
None	Dragged right leg at 28 years. At 34 years weakness, spasticity and increased reflexes right arm, right leg and left leg	None	Not reported
None	Mainly a spastic right leg	No initial treatment. Laminectomy 5 years after accident. No marked improvement in nervous disorder	Non-union
Numbness below the neck. Weakness of all limbs	None	Reduction by traction. Plaster collar for 14 weeks	Not reported
None	None	Reduction. Plaster for 3 months. Celluloid collar 2 months	Bony union
None	None	Reduction. Plaster for 3 months. Celluloid collar 2 months	Bony union
Not stated	Paresis, paraesthesia, hypoaesthesia of all limbs 19 years after injury	None initially. Laminectomy and occipito-cervical fusion	Non-union
None	Quadraplegia	No initial treatment	Not reported
None	None	Reduction by head traction. Minerva plaster worn for 3 months.	Bony union
None	None	Ditto	Not stated
None	None	Ditto	Not stated
None	None	None	Not stated
None	None	Head traction. Period not stated	Non-union
Paraesthesia ulnar aspects of both the hands	None.	Head traction for 4 weeks. Plaster jacket for further 12 weeks. Spinal fusion at 16 weeks	Non-union at 16 weeks
None	None	Traction by Glisson sling begun at 5 weeks. Reduction after 3 weeks. Plaster	Bony union
Transient paraplegia, ageusia, dysphagia, occipital neuralgia	None	Plaster jacket for 3 months	Not stated
None	None	Manipulation. Plaster. Period not stated	Not stated
None	None	Plaster collar applied at 4 days. Removed at 6 days. Plaster collar for 1 year	Not stated
None	None	Plaster for 8 weeks. Plastic collar thereafter	Not stated
None	None	Plaster for 3 months	Bony union

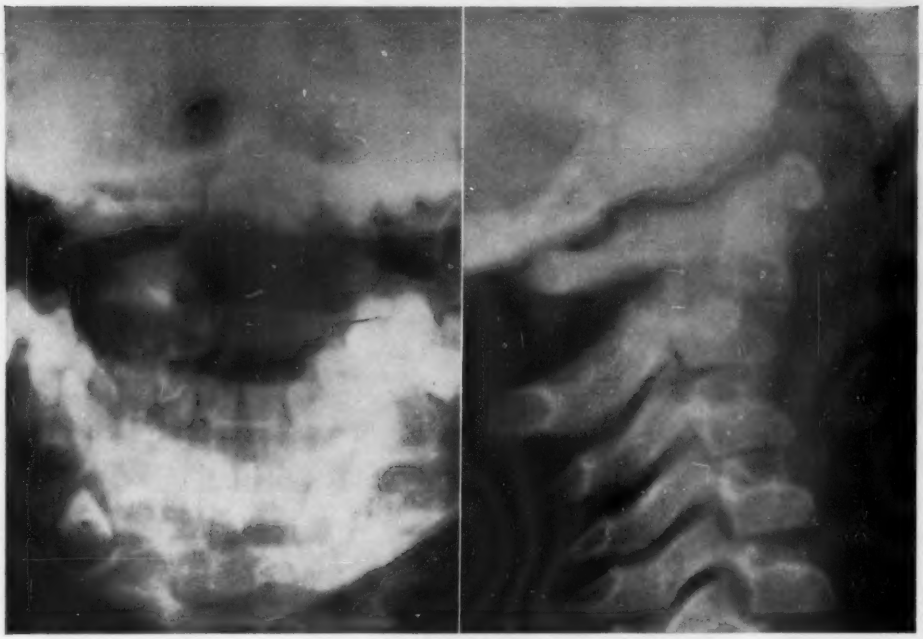

FIG. 3

FIG. 4

Figure 3—Case 11. Figure 4—Case 10. These radiographs were taken on admission to hospital, within a few hours of the injuries. Note the difficulty of defining the fracture-line in the antero-posterior views. The shadow across the base of the odontoid process in Figure 4 is caused by the overlying arch of the atlas, and is not the fracture-line. (Patients of Mr D. Ll. Griffiths.)

FIG. 5 FIG. 6 FIG. 7

Case 10—Fracture of the odontoid in a child of four years and six months. Figure 5—Radiograph seven weeks after injury showing union of the fracture with slight forward displacement. Figures 6 and 7—Lateral radiographs taken three years after the injury, with the head in full flexion (Fig. 6) and in full extension (Fig. 7).

old epiphysial cartilage (Fig. 21). There is no evidence that the odontoid process fractures at any other site in children over seven years, in adolescents, or in adults.*

At the usual site of fracture the cortex of the odontoid is thinner and the cancellous trabeculae are more sparse than in the process itself (Fig. 8). The displacing fragment of bone is grasped by the anterior arch of the atlas and the transverse ligament, both of which are

TABLE III

FRACTURES OF THE ODONTOID PROCESS IN CHILDREN UNDER SEVEN YEARS OF AGE (FIVE CASES)

Direction of displacement	Forward	5
	Backward	0
Neurological complications	Early	1
	Late	0
Site of fracture	At base of odontoid	0
	At epiphysial plate	5
Outcome of fracture	Bony union	5
	Non-union	0

in contact with the process above the level of the fracture. The alar ligaments binding the fragment to the occiput are attached to the apex of the odontoid. The stability of the occiput on the cervical vertebrae depends upon the integrity of the odontoid process, for the capsules of the atlanto-axial joint are loose, and do not contribute to the stability of the spine. When the odontoid process is fractured there is very little to prevent subluxation of the atlas on the axis, which displacement may occur immediately the fracture is sustained, or later.

In this series forty-six fractures occurred in patients over seven years of age (Table IV). The four fractures in older children exactly resembled the forty-two fractures in adults in behaviour and in site.

* We consider that one of the cases reported by Hamilton (1951) represents an ununited apical apophysis and not a fracture through the apex of the odontoid as he believed.

In twelve patients the odontoid fragment was undisplaced, in twenty-two patients it was displaced forwards, and in twelve patients it was displaced backwards (Tables V to VII). The degree of deformity varied considerably, but forward displacement was nearly twice as common as backward displacement (Table IV).

FIG. 8

Radiographs of thin sections of the odontoid process and adjoining body of the axis, showing the thinner cortex and more sparse cancellous trabeculation in the lower part of the odontoid and in the body. The arrow indicates the junction.

MECHANISM OF PRODUCTION OF THE FRACTURE

(Adults and Children)

The odontoid is fractured by considerable violence, usually applied to the head, but occasionally to the neck. In our series one child fell from a bedroom window. Most of these fractures, however, are the result of road accidents. Two of our patients were cyclists. One

TABLE IV

FRACTURES OF THE ODONTOID PROCESS IN PERSONS OVER SEVEN YEARS OF AGE (FORTY-SIX CASES)

Cases collected from the literature	37
New cases reported in this paper	9
Displacement	
No displacement	12
Forward displacement	22
Backward displacement	12
Outcome of fracture	
Not known	11
Bony union	13
Absence of bony union	22

ran into a wall, the other into the back of an attendant when cycling on a racing track. One patient fell from a motor-cycle and three were pedestrians knocked down by vehicles. Another patient, the driver of a car, was thrown forwards, striking his chin on the steering wheel.

Blows on the back of the head produce a forward displacement. Violence to the face

may produce a forward or a backward displacement. One of our patients sustained a blow on the forehead, and his odontoid fragment was displaced backwards. In two of our patients with a forward displacement of the odontoid there was a fracture of the mandible in one and a laceration at the tip of the chin in the other. The blows struck the lower part of their

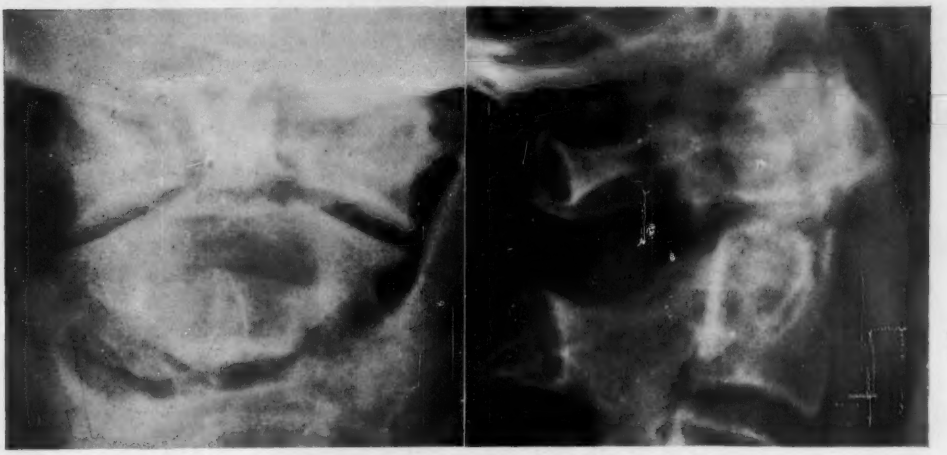

FIG. 9

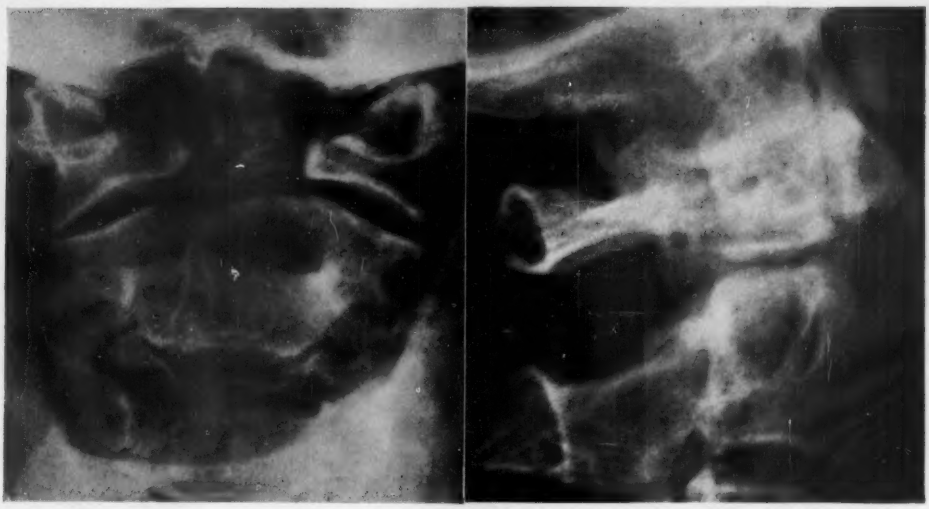

FIG. 10

Case 1—Fracture of the odontoid in an adult of sixty years. Figure 9—Original fracture. Figure 10—Three years later. The fracture is ununited. (Patient of Mr D. Ll. Griffiths.)

face. Since the mandible lies below the occipito-atlantal joint, a blow on the chin levers the head into flexion.

In three of our patients, abrasions or lacerations on one side of the face only, and in one patient, a depressed fracture of the skull, indicated that the violence had been applied to the side of the head, and flexion and extension of the neck, if either occurred, must have been combined with sudden rotation.

We have not succeeded in producing a fracture of the odontoid in post-mortem experiments by imitating any of these mechanisms of injury. Flexion, extension or rotation, even when the lower cervical spine had been stabilised, have failed to produce any fracture of the cervical spine. This evidence is not in any way conclusive, for the absence of muscle tone and loss of elasticity of body tissues after death probably alter the character of resistance to any applied force.

We conclude that any violence to the head which throws it into extreme flexion, extension or rotation may avulse the odontoid process, the pull of the alar ligaments being responsible for the avulsion. Once a fracture has occurred at the base of the odontoid, the atlas can subluxate and carry with it the detached odontoid. The subluxation is forwards when the mechanism is flexion, and backwards when one of extension. In rotation, which it would be reasonable to assume never occurs alone, the displacement of the odontoid depends on whether this force is combined with flexion or with extension.

TABLE V

TWELVE FRACTURES OF THE ODONTOID WITHOUT DISPLACEMENT

Early neurological complications	0
Late neurological complications	1
Outcome of fracture	
Not known	1
Bony union	3
Non-union	8

CLINICAL FEATURES

There is no diagnostic clinical syndrome of fracture of the odontoid. Indeed, the symptoms and signs may be so few and so indefinite that the diagnosis is missed. Usually the immediate pain is severe, and is often referred into the occipital region of the scalp. The pain is accentuated by any attempt to move the head. The classical clinical picture is of a man supporting his head with his hands in order to prevent the slightest movement. The neck may be held twisted, which makes radiography difficult. Such symptoms and signs were seen in six of our patients, in all of whom the odontoid fragment had been considerably displaced.

If displacement has not occurred, or is of trivial degree, there may be little pain, but then there will certainly be some stiffness of the neck. In such patients the fracture may be easily overlooked until late displacement makes it more obvious.

NEUROLOGICAL COMPLICATIONS

The commonest neurological complication seen in the survivors of this fracture is damage to the greater occipital nerve, giving the referred pain in the occiput, which we have already mentioned. Damage rather nearer the central nervous axis may be responsible for the dysphagia and anomalies of taste of which patients sometimes complain.

Obviously however the most serious complication to be found is immediate damage to the spinal cord or medulla oblongata. It is possible that many patients with fractures of the odontoid never reach hospital at all because they sustain a fatal injury to the vital centres at the moment of fracture.

Three of our eleven patients showed immediate evidence of spinal cord damage. One had a hemiplegia and hemi-anaesthesia, and one of the children had pyramidal signs (abdominal reflexes absent, and plantar responses extensor). The other adult had an incomplete tetraplegia. The right arm was paralysed, the left arm was weak, and there were pyramidal signs in the lower limbs. In the cases of the adults there was backward displacement, in the child forwards.

In the forty that we have collected from the literature four patients had an immediate paraplegia of varying severity. Three of these had fractures with backward displacement, and only one with forward displacement, though in the whole series forward displacement was nearly twice as common as backward. It therefore appears that at the time of the injury backward displacement is much more dangerous than forward.

ASSOCIATED INJURIES

Two of our eleven patients and two of the forty previously reported had fractures of the mandible, as well as of the odontoid. This is the commonest associated injury. One adult had a fracture of the humerus, one had a brachial plexus palsy, and two had a fracture of the skull. None of our eleven patients had fractures lower in the cervical spine; indeed, such has only been reported once. Only one of our own cases supported Jefferson's (1927) statement that a fracture of the odontoid may be associated with a fracture of the atlas.

TABLE VI

TWENTY-TWO FRACTURES OF THE ODONTOID WITH FORWARD DISPLACEMENT

Early neurological complications	1
Late neurological complications	11
Outcome of fracture	
Not known	7
Bony union	3
Non-union	12

TABLE VII

TWELVE FRACTURES OF THE ODONTOID WITH BACKWARD DISPLACEMENT

Early neurological complications	5
Late neurological complications	0
Outcome of fracture	
Not known	3
Bony union	7
Non-union	2

LATE PARAPLEGIA

The evil reputation of fractures of the odontoid arises partly from the occasional occurrence of late paraplegia. We have seen no example of this. Paraplegia is known to have developed two months or more after the injury in eleven out of twenty-two patients with forward displacement (Table VI), and in one with an undisplaced fracture (Table V). Such " late " paraplegia has not been reported in cases with backward displacement (Table VII), and has not occurred in any of the fractures of early childhood (Table III).

The time of onset of late paraplegia varies from two to three months after the injury to as long as twenty-eight years later (Table VIII). This complication arises most commonly within one year of injury. The onset of the symptoms may be gradual, sudden, or precipitated by such an incident as a sneeze. The paralysis may be intermittent, at least in its early stages. It may take the form of a monoplegia, paraplegia, tetraplegia or hemiplegia.

Study of the accounts of cases in which neurological signs developed late leads to two main conclusions. First, there was in all cases evidence of " slipping " of the fracture, and it is, therefore, reasonable to assume that movement at the site of the fracture may be the chief cause of damage to the spinal cord. Second, none of the patients who developed late paraplegia had received what we would consider adequate treatment in the early days of the

fracture (Table VIII). Indeed, in none of them had the neck been immobilised in the first few months, and many had had no treatment at all until paralysis developed. Conversely, none of the patients who received early and adequate treatment of the fracture developed paralysis, even though the fracture remained ununited by bone (Table IX).

TABLE VIII

THE DEVELOPMENT OF LATE NEUROLOGICAL COMPLICATIONS IN TWELVE CASES

	Time after fracture			
	About 1 month	2 months to 1 year	1 year to 5 years	After 5 years
Nerve involvement locally	1	—	—	—
Gradual onset monoplegia	—	1	1	1
Gradual onset paraplegia	—	2	—	—
Gradual onset tetraplegia	—	1	1	1
Sudden onset hemiplegia .	—	1	—	—
Paraesthesia in hands .	—	1	—	1

Relation to Treatment	
	No immobilisation at all . . . 5
	No immobilisation in first few months 7
	Treatment considered adequate . . 0

TABLE IX

THE RELATIONSHIP OF ABSENCE OF BONY UNION TO THE TREATMENT GIVEN AND TO LATE NEUROLOGICAL COMPLICATIONS (TWENTY-TWO CASES OF NON-UNION)

	Undisplaced	Displacement forwards	Displacement backwards	Late neurological complications
No treatment . .	1	2	—	1
None for first month	2	5	—	5
Treatment inadequate	2	3	1	3
Treatment adequate .	3	2	1	0

Of the three other cases with late neurological complications, one is described as uniting with plentiful callus, and in the other two, absence of bony union cannot be definitely established

UNION OF FRACTURES OF THE ODONTOID

Twenty-two of the thirty-five fractures of which the outcome is known failed to unite by bone. This is a high rate of non-union. Sixteen of these twenty-two patients received no initial treatment, or treatment so poor as to be of no consequence, but six patients in whom non-union occurred received periods of immobilisation which would be thought adequate (Table IX). Three of our cases, all over sixty years of age, developed non-union in spite of early treatment. The feature they had in common was the presence of osteoarthritis of the cervical spine.

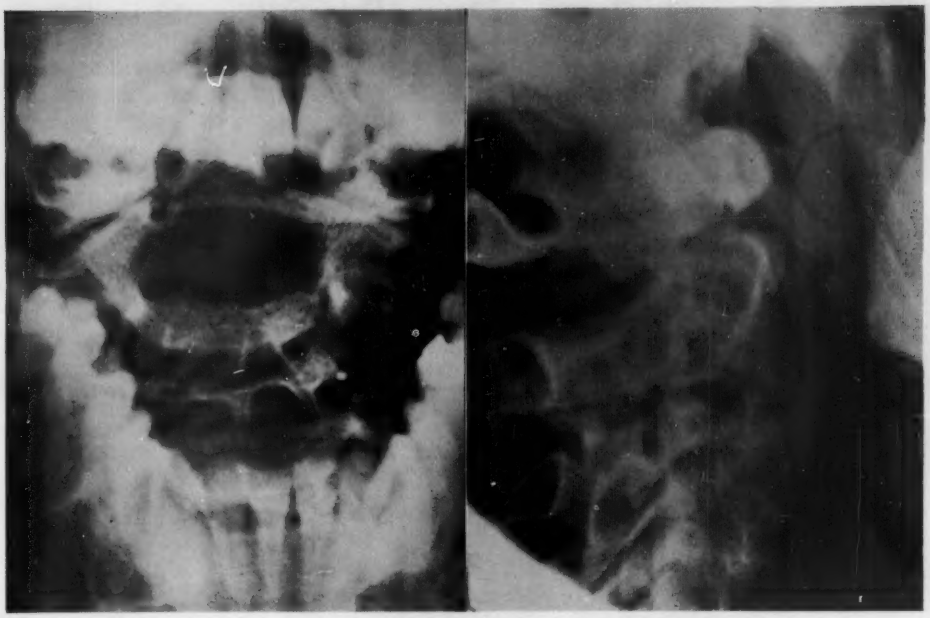

FIG. 11

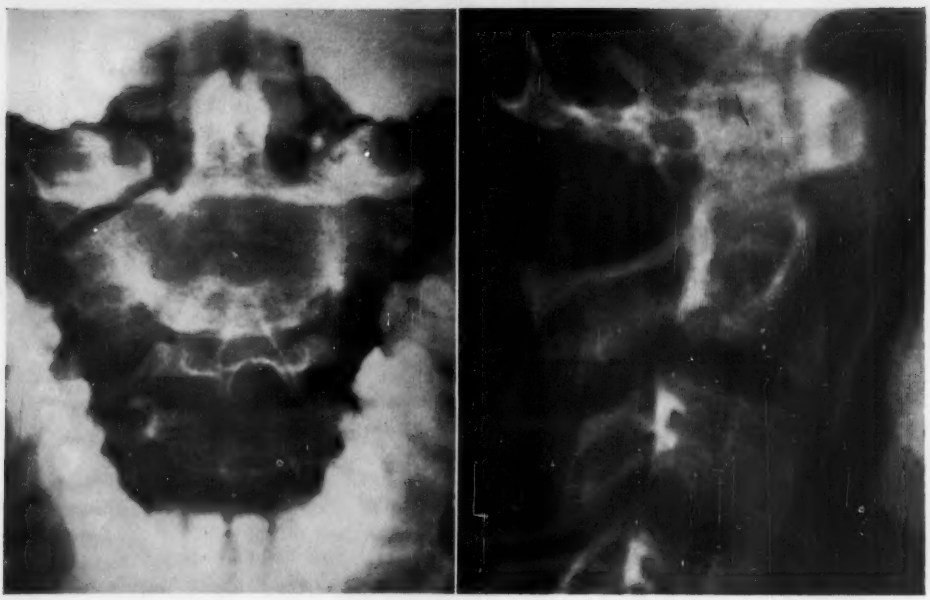

FIG. 12

Case 2—Fracture of the odontoid in a man of nineteen years. Figure 11—Initial radiographs. Figure 12—Two years later. A case showing bony union. Note in Figure 11 the remnant of the epiphysial plate (*cf.* Fig. 1) lying in the body of the bone quite distinct from the fracture-line. (Patient of Mr J. Charnley.)

This failure of union is not related to the direction of displacement, for it occurred in cases in which the odontoid fragment was displaced backwards, in which it was displaced forwards, and even in which it was not displaced at all (Table IX). Bony union occurred either in cases in which immobilisation commenced shortly after the injury and was continued for at least three months, or in cases in which an operation for fusion of the spine was performed.

So far as can be determined from the reported cases and from our own follow-up studies, firm fibrous union is compatible with safety. A mobile pseudarthrosis permits considerable backward and forward movement of the atlas on the axis, as a result of which the spinal cord may be damaged either by attrition or by one sudden movement which exceeds the safe limits. Such mobile pseudarthrosis occurs only from inadequate primary treatment.

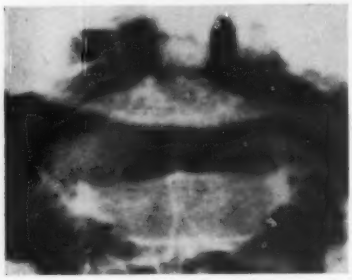

FIG. 13

Case 5—Fracture of the odontoid in a woman of twenty-two. Radiograph taken eight months after injury showing the development of non-union—the " rarefying osteitis " of the previous writers. (Patient of Mr J. Charnley.)

The firmness and the safety of good fibrous union after adequate treatment can be determined from radiographs taken in full flexion and full extension. Such films in such cases show little or no movement at the fracture. The relations of the fragments of the axis remain constant, and there is no tendency for the atlas to subluxate with the passing of time.

Evidence of non-union can be obtained from the antero-posterior radiographs. Rarefaction appears around the fracture after about three months (Fig. 13). The fracture line may then appear wider, the opposed surfaces become well defined, and ultimately sclerose (Figs. 9 and 10 and 14 to 17). These changes indicate non-union of the fracture, and there seems to be no justification to describe them as " rarefying osteitis," " fibrosing osteitis," or " secondary osteoporosis." These are the usual changes seen in non-union of fractures through cancellous bone.

When bony union occurs there is no ensheathing callus to be seen, nor is there any tendency for the odontoid to fuse with the anterior arch of the atlas. In our cases, lateral radiographs taken in flexion and extension have demonstrated normal movement of the anterior arch of the atlas at the anterior articular facet of the odontoid process.

As stated previously, odontoid fractures in children appear to unite by bone quite readily.

TREATMENT

The displaced odontoid fragment carried backwards or forwards by the subluxating atlas can be replaced by traction. Roberts (1937) suggested that a leather harness should be used in cases of fracture-dislocation of the cervical spine treated by continuous traction. This is, however, an uncomfortable appliance; the mouth cannot be opened, and pressure sores may develop on the chin and over the occiput. The caliper devised by Crutchfield (1936) for insertion into the outer table of the skull vault is better and has been used in our cases even in children. If the mandible be fractured, as it was in two of our cases, splints can be applied. The position of the caliper helps reduction, for if it is placed towards the back of the skull the head tends to be flexed, and if towards the front, extension occurs.

The caliper is inserted after the infiltration of the scalp with a local anaesthetic; general anaesthesia, which could be dangerous, should be avoided. With the patient supine, the shoulders at the end of the mattress and the head supported on pillows, traction is applied through the caliper by a weight, cord and pulley (Fig. 18). By gradually increasing the traction during twenty-four or forty-eight hours the fracture can be distracted. Then, by adjusting

the pillows under the head, so flexing or extending the head, the fragments are brought into alignment. The weight is then reduced. Radiographs are taken frequently to check the progress of reduction (Figs. 21 to 23).

For six weeks the head and neck are immobilised by continuous traction. At the end of this time a Minerva plaster is applied. We have done this sectionally, as recommended by Charnley (1954). The patient is turned on to his face, and a posterior shell extending from occiput to pelvis is constructed (Fig. 19). This is removed and dried. The patient then lies

FIG. 14

FIG. 15

FIG. 16

FIG. 17

Case 7—Fracture of the odontoid in a man of sixty. Radiographs showing the development of non-union. Figure 14—At the time of injury. Figure 15—At three months. Figure 16—At nine months. Figure 17—At two years and three months. Note the erosion at the fracture line giving way to sclerosis, and also the development of osteoarthritis at the atlanto-axial joints. (Patient of Sir Harry Platt.)

on the dry shell, which for the completion of the plaster is supported between two tables. The caliper is incorporated in the plaster (Fig. 20). Immobilisation is continued for a further six weeks.

This programme is recommended for the displaced fracture. In our experience, however, light traction with the Crutchfield caliper affords comfortable and adequate immobilisation, even for undisplaced fractures. If this be followed by a period of immobilisation in plaster a safe state of bony union (Figs. 12 and 23) or close fibrous union (Figs. 10 and 17) will result.

Displacement of a fracture which has been adequately reduced can occur during the period of immobilisation in plaster. An example of this rare event was Case 4 (Table I). In

this case a posterior spinal fusion, using chips of cancellous bone taken from the iliac crest and augmented by a wire fixation of the spinous processes, was performed. Fusion of the occiput to the posterior elements of the atlas and axis resulted, and bony union of the fracture occurred.

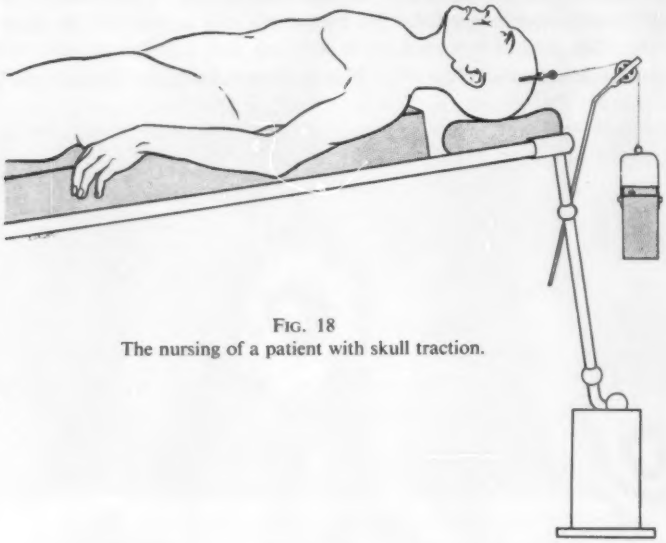

FIG. 18
The nursing of a patient with skull traction.

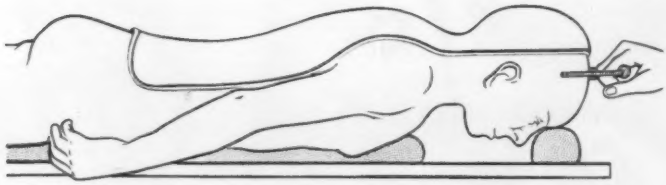

FIG. 19
Making the posterior plaster shell.

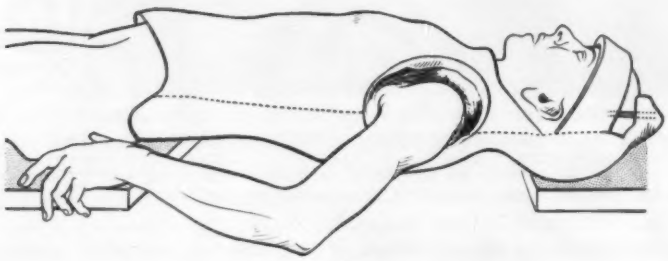

FIG. 20
The completion of the Minerva plaster.

RESULTS

The literature on this fracture contains few accounts of the ultimate results in adequately treated patients. We have succeeded in tracing ten patients for periods of up to four years, and we can report that in two young children bony union occurred, and imperfections of reduction were smoothed off. Of the nine fractures in adults only four treated conservatively united by

bone. Two patients were examined two years after the injury. One was serving in the Royal Air Force and the other was employed as a forester. Neither had any disability, although one complained of aching at the back of the neck on full extension. Radiographic studies showed that normal movement occurred between the atlas and the axis.

One patient, who had had an occipito-cervical fusion, was free from symptoms two years after the operation, and had a good range of movement. Although she could not nod the head there was an almost full range of flexion, extension and lateral movement. Rotation was possible through half the normal range.

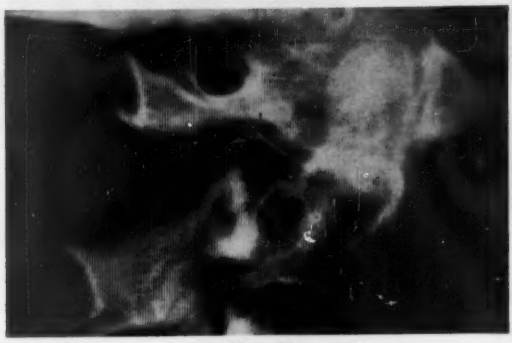

FIG. 21

FIG. 22

FIG. 23

Case 8—Fracture of the odontoid in a man aged thirty-three years. Figure 21—Radiograph before traction applied to skull caliper. Figure 22—The position of reduction. Figure 23—Union of the fracture three months after injury. (Patient of Mr D. Ll. Griffiths.)

There were four cases of non-union. They had been observed over periods of two and a half to four years. Their disability was slight—an occasional ache and a terminal limitation of movement. Radiographs taken in flexion and extension demonstrated some movement of the odontoid fragment. None developed neurological signs.

SUMMARY AND CONCLUSIONS

1. Fifty-one cases of fracture of the odontoid have been analysed. Forty were reported by other surgeons; eleven were new cases first reported by us.
2. Fracture of the odontoid in young children is an epiphysial separation. It occurs up to the age of seven years. As in epiphysial separations elsewhere, it unites readily, and remodelling occurs when reduction has been incomplete, so that normal anatomy is restored.

3. In adults forward displacement is twice as common as backward displacement.
4. Immediate paralysis is commoner if backward displacement occurs, but late neurological disorders are seen only after fractures with forward displacement.
5. Failure of bony healing is not dangerous if treatment has resulted in firm fibrous union, for there is neither excessive abnormal mobility nor progressive subluxation, either of which could injure the spinal cord or medulla. Neurological disorders developing after the fracture are the result of mobility from inadequate early treatment. It is the results of inadequate early treatment which have given this fracture a sinister reputation.
6. The fracture should be reduced by skeletal traction through a skull caliper. The reduction should be maintained for six weeks by continuous traction, and this should be followed by a period of six weeks in a plaster.
7. The increasing definition of the fracture-line seen in the radiographs of some patients indicates non-union.

We wish to express our thanks to Mr D. Ll. Griffiths, the Director of the Department in which this work was carried out, for permission to publish some of his cases, and for reading this manuscript; to Mr John Charnley for permission to publish some of his cases; to Sir Harry Platt for permission to publish one of his cases; to Sir Geoffrey Jefferson for permission to publish one of his cases; to Mr M. E. Winston for permission to mention his case; and to Mr A. Ronald for permission to publish his case.

REFERENCES

ANDERSON, C. B. C. (1932): Fracture of the Odontoid Process of the Axis. Journal of the Royal Army Medical Corps, **59,** 371.
ANDERSON, R., and BURGESS, E. (1939): Improved Radiographic Technic for Visualizing Odontoid Process. Northwest Medicine, **38,** 388.
ANGELESCO, A., and BUZOIANU, G. V. (1931): Fracture de l'axis sans symptomes médullaires. Revue d'Orthopédie, **18,** 201.
BARDEEN, C. R. (1910): *In* Manual of Human Embryology, p. 353. Edited by F. Keibel and F. P. Mall. Philadelphia and London: J. B. Lippincott Company.
BERNSTEIN, R. (1903): Zur Diagnose und Prognose der Rückenmarksverletzungen. Deutsche Zeitschrift für Chirurgie, **70,** 175.
BULL, G. M. (1942): The Syndrome of Atlanto-axial Dislocation. Clinical Proceedings, **i,** 336.
CHARNLEY, J. (1954): Personal communication.
COLSEN, K. (1949): Atlanto-axial Fracture-dislocation. Journal of Bone and Joint Surgery, **31–B,** 395.
CONE, W., and TURNER, W. G. (1937): The Treatment of Fracture-dislocation of the Cervical Vertebrae by Skeletal Traction and Fusion. Journal of Bone and Joint Surgery, **19,** 584.
CORNER, E. M. (1907): Rotary Dislocations of the Atlas. Annals of Surgery, **45,** 9.
CRAIG, W. McK. (1931): Fracture Dislocation of the Cervical Vertebrae with Injury to the Spinal Cord. Surgical Clinics of North America, **11,** 841.
CROOKS, F., and BIRKETT, A. N. (1944): Fractures and Dislocations of the Cervical Spine. British Journal of Surgery, **31,** 252.
CRUTCHFIELD, W. G. (1936): Further Observations on the Treatment of Fracture Dislocations of Cervical Spine with Skeletal Traction. Surgery, Gynecology and Obstetrics, **63,** 513.
DÜRCK, H. (1930): Über Epistropheus-Brüche. Beiträge zur pathologischen Anatomie und zur allgemeinen Pathologie, **84,** 353.
EASTWOOD, W. J. (1940): Discussion on Fractures and Dislocation of the Cervical Vertebrae. Proceedings of the Royal Society of Medicine (Section of Orthopaedics), **33,** 651.
ELLIOTT, R. G., and SACHS, E. (1912): Observations on Fracture of the Odontoid Process of the Axis with Intermittent Pressure Paralysis. Annals of Surgery, **56,** 876.
FRITZSCHE, E. (1912): Über die Frakturen des Zahnfortzatzes des Epistropheus. Neue röntgenographische Darstellung des Processus odontoideus. Deutsche Zeitschrift für Chirurgie, **120,** 7.
GROGONO, B. J. S. (1954): Injuries of the Atlas and Axis. Journal of Bone and Joint Surgery, **36–B,** 397.
HAMILTON, A. R. (1951): Injuries of the Atlanto-axial Joint. Journal of Bone and Joint Surgery, **33–B,** 434.
HEUBLEIN, G. W. (1944): The Roentgen Diagnosis of Traumatic Lesions of the Cervical Spine. Journal of the American Medical Association, **126,** 951.
JEFFERSON, G. (1927): Remarks on Fractures of the First Cervical Vertebra. British Medical Journal, **ii,** 153.
JUDD, G. (1943): A Useful View of the Odontoid Process of the Axis Vertebra. Radiography, **9,** 46.

KAHN, E. A., and YGLESIAS, L. (1935): Progressive Atlanto-axial Dislocation. Journal of the American Medical Association, **105,** 348.
KOLISKO, A. (1916): Über den Bruch des Processus odontoides, des. 2. Halswirbels bei Stirntrauma. Virchow's Archiv, **222,** 1.
LAMBOTTE, A. (1894): Un cas de fracture ancienne de l'apophyse odontoide avec luxation de l'atlas en avant. Annales de la Société de Médecine d'Anvers, **56,** 131.
LANDE, P., and DERVILLÉE, P. (1934): Traumatisme de la colonne cervicale. Annales de Médecine Légale, **14,** 785.
LEPEUPLE, E., and PARNEIX, H. (1937): Un cas de fracture isolée de l'apophyse odontoide de l'axis. Revue d'Orthopédie, **24,** 166.
MAGNANT, J. S. (1931): Les fractures de l'apophyse odontoide de l'axis. Revue de Chirurgie, **69,** 13.
MEYERDING, H. W. (1935): Fracture of the Odontoid Process. Proceedings of the Staff Meetings of the Mayo Clinic, **10,** 710.
MIXTER, S. J., and OSGOOD, R. B. (1910): Traumatic Lesions of the Atlas and Axis. Annals of Surgery, **51,** 193.
MURPHY: quoted by OSGOOD and LUND.
OSGOOD, R. B., and LUND, C C. (1928): Fractures of the Odontoid Process. New England Journal of Medicine, **198,** 61.
PILCHER, L. S. (1910): Atlanto-axial Fracture-dislocation. Annals of Surgery, **51,** 208.
PLAUT, H. F. (1938): Fractures of the Atlas Resulting from Automobile Accidents. American Journal of Roentgenology, **40,** 867.
REICH, R. S. (1938): Posterior Dislocation of the First Cervical Vertebra with Fracture of the Odontoid Process. Surgery, **3,** 416.
ROBERTS, S. M. (1937): Fractures and Dislocations of the Cervical Spine. Journal of Bone and Joint Surgery, **19,** 199, 477.
ROGERS, W. A. (1942): Treatment of Fracture-dislocation of the Cervical Spine. Journal of Bone and Joint Surgery, **24,** 245.
RYAN, C. (1931): Injuries to the Upper Cervical Vertebra. International Journal of Medicine and Surgery, **44,** 209.
SCHWARZ, G. A., and WIGTON, R. S. (1937): Fracture-Dislocations in the Region of the Atlas and Axis, with Consideration of Delayed Neurological Manifestations and some Roentgenographic Features. Radiology, **28,** 601.
SMITH, S. (1872): Quoted by Wüsthoff, R. (1923): Deutsche Zeitschrift für Chirurgie, **183,** 73.
TAVERNIER, L. (1931): Luxations de la colonne vertébrale à déplacement progressif. Leur traitement par la greffe interépineuse. Revue d'Orthopédie, **18,** 562.
TIPPETT, G. O. (1951): Atlanto-axial Fracture-dislocation. Journal of Bone and Joint Surgery, **33–B,** 108.
WILLARD, D. P., and NICHOLSON, J. T. (1941): Dislocation of the First Cervical Vertebra. Annals of Surgery, **113,** 464.
WINSTON, M. E. (1954): Personal communication.
WÜSTHOFF, R. (1923): Über die Luxationsfraktur im unteren Kopfgelenk. (Atlas-Epistropheus-Gelenk.) Deutsche Zeitschrift für Chirurgie, **183,** 73.

STRESS FRACTURES OF THE FIBULA

A Review of Fifty Cases in Athletes

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From the Middlesex Hospital

Stress fractures of the lower part of the fibula are common in athletes. This paper reviews fifty such injuries and discusses the natural history, signs, symptoms, radiographic appearances and treatment. All were seen in the Athletes' Clinic at the Middlesex Hospital between 1952 and 1955, at which they represented an approximate incidence of 3 per cent of new patients seen.

An excellent summary of the literature was given by Burrows (1948), who recorded twenty-four stress fractures of the lowest third or middle third of the fibula, and a larger number in the uppermost third. Since then ten more have been published, eight in children, by Griffiths (1952) and two by Richmond and Shafor (1955). The high incidence in athletes has not been noted before.

CLINICAL MATERIAL

Table I gives details of the present series. All the fractures were confirmed radiologically. The circumstances in which they occurred have been studied in the thirty-one patients whom we have been able to follow up. The remainder could not be traced. Five stress fractures of the fibula seen during the same period, but not in athletes, are excluded from the series.

FIG. 1

A marathon runner aged thirty-eight felt a sudden pain in his leg at the twenty-second mile. He had sustained a stress fracture in the mid-shaft of the fibula. The downward and inward direction of the fracture line is unusual.

The conditions of sport and state of training were investigated (Table II), and it is apparent that running on hard surfaces was the most common and, we believe, important factor in the etiology.

HISTORY

The patients usually presented themselves about ten days after the onset of symptoms, but occasionally within twenty-four hours. The onset was abrupt or insidious, and this divided the series quite sharply into two groups (Table III). Those with an abrupt onset experienced severe pain which was felt suddenly above and behind the outer side of the ankle; the patient had no doubt that at one moment he was normal and the next painfully crippled. The oldest man in the series came into this category; he was a marathon runner aged thirty-eight who experienced a sudden acute pain at the end of his twenty-second mile (Fig. 1). An insidious onset was rather more common. There was no particular moment when the symptoms started but a gradually increasing pain became apparent either during or after activity.

The pain was frequently spoken of as being behind the ankle and the patient located the tender spot well to the back of the fibula. Sometimes a swelling was noticed above the lateral malleolus. Walking was possible with a greater or lesser degree of limp, but running or going upstairs caused pain at the site of the fracture.

TABLE I

CLINICAL DETAILS OF STRESS FRACTURES OF THE FIBULA IN ATHLETES
(Forty-nine athletes: fifty fractures)

Type of sport		Sex		Site	
Running	46	Male	46	Left	26
Football	2	Female	3	Right	22
Squash rackets	1			Bilateral	1

TABLE II

CONDITIONS AND TRAINING IN THIRTY-ONE ATHLETES WITH STRESS FRACTURES SEEN AT FOLLOW-UP

Running on hard roads	16		
Running on hard surfaces	9		
Playing football	2		
Long jumping*	1		
Squash rackets	1		
Running on soft ground (One case bilateral)	2		
In training	30	Usual sport	29
Out of training	1	Unusual sport	2

* This athlete was normally a middle distance runner.

TABLE III

MODE OF ONSET OF THIRTY-ONE STRESS FRACTURES

Abrupt	12	Insidious	19

DIAGNOSIS

Stress fractures of the fibula can be recognised without difficulty if the characteristic history and physical signs are appreciated.

Clinical examination always shows an area of tenderness, usually just above the lateral malleolus, and pain is elicited at this site by pressing the fibula towards the tibia. Swelling is present at this level in severe and in late cases, and, although soft and tender at first, it becomes bony hard after a time. The appearance of the swelling is shown in Figures 2 and 3.

FIG. 2

FIG. 3

Figure 2—Only by comparing both ankles with the legs internally rotated can the swelling above the right lateral malleolus be seen with ease. Figure 3—The radiographs show the stress fracture clearly five weeks after the onset of symptoms.

FIG. 4

In a radiograph taken two weeks after the onset of symptoms a slight periosteal reaction could be seen when the film was held to a naked bulb. At four weeks (*above*) the typical appearances of a stress fracture are seen.

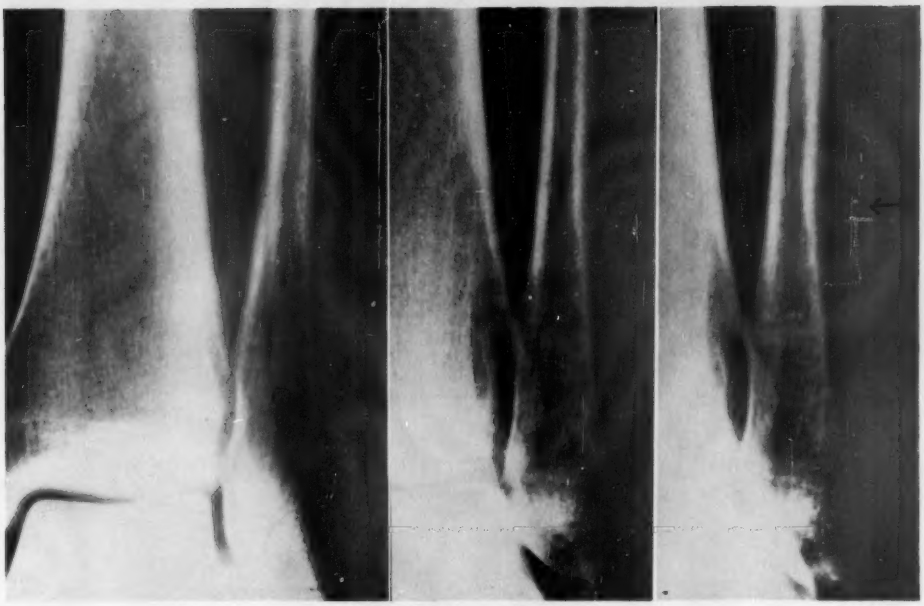

FIG. 5 FIG. 6 FIG. 7

The radiographic changes of stress fractures of the fibula frequently appear late. In Figure 5 no abnormality is seen ten days after the onset of symptoms, and in Figure 6 at four weeks the changes are slight. At six weeks (Fig. 7) the periosteal new bone and the fracture are seen more clearly.

FIG. 8

Nine weeks after this stress fracture occurred the fracture line is clearly visible and callus is consolidating about it.

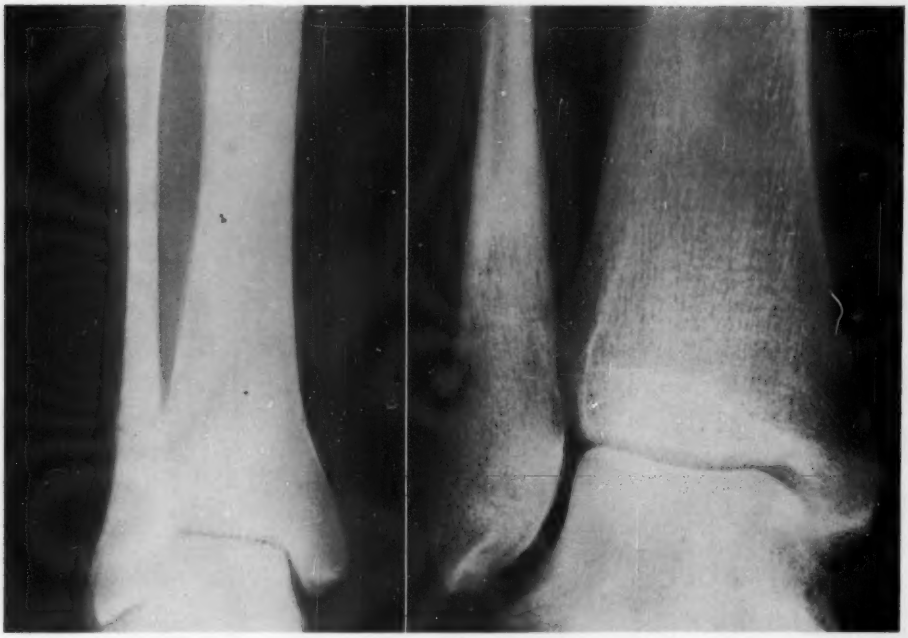

FIG. 9 FIG. 10

Figure 9—This fracture could be seen clearly two weeks after the onset. Figure 10—Three years later buttressing can still be seen at the fracture site.

FIG. 11 FIG. 12

More than one projection may be required to show a stress fracture. Here the antero-posterior view (Fig. 11) appears normal but an oblique view (Fig. 12) shows a small mass of new bone which confirmed the clinical diagnosis.

The two ankles are most easily compared when the legs are rotated a little inwards so that the fibulae are seen in profile.

It is important to realise that radiological changes are late, and often the typical appearance cannot be seen for four weeks (Fig. 4). Figures 5 to 7 show an example in which they were clearly seen only six weeks after the onset of symptoms. In most patients the first change that may be just visible after some two weeks is a hazy patch of new bone on the postero-lateral aspect of the fibula just above the inferior tibio-fibular joint. This thin callus will not be seen unless the film is inspected against a naked bulb, because in routine radiographs

FIG. 13

FIG. 14

A macrograph carefully centred (Fig. 13) may show the fracture when normal radiographs do not (Fig. 14). Here both are reproduced in relative sizes.

of the ankle this part of the fibula is, of necessity, " over-exposed." Later, when the callus has consolidated, it is clearly visible and the fracture line may be seen running through the cortex (Fig. 8).

In a few patients the fracture line was clearly seen from the onset, or a few days later, and occasionally there were traces of it many years later (Figs. 9 and 10). Oblique and lateral views may show a fracture not visible in antero-posterior projections (Figs. 11 and 12). In the early stages a " macrograph " carefully centred over the tender area will often reveal the fracture line or a little callus not visible on ordinary non-magnified films (Figs. 13 and 14).

THE LEVEL OF FRACTURE

Stress fractures of the fibula have been classified according to the level, but in this series it was impossible to distinguish between fractures of the lowest third and middle third from the history of the mechanism of injury, and apart from the actual site of the lesion the symptoms and signs were identical. Analysis of forty radiographs in which the level of the fracture could be identified accurately shows an overwhelming preponderance in the lowest third of the bone (Fig. 15).

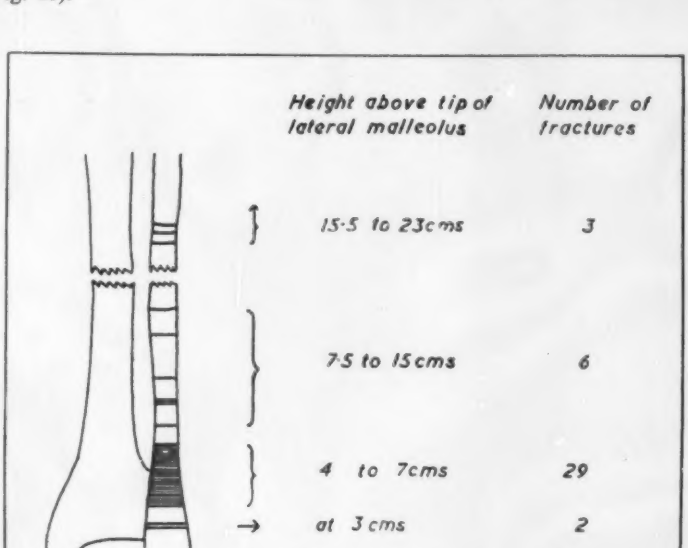

FIG. 15
Level of fracture in forty athletes.

No stress fracture in the uppermost third of the fibula is included in this series but there are many recorded in the literature. Several patients with fractures from muscle violence in this region have been seen but were excluded from this study; the radiographs of one patient with this condition are shown in Figures 16 to 18. In this instance a careful history showed that the injury occurred from one sudden badly coordinated muscular contraction and not from long-continued and repetitive muscular exertion. None of the athletes with stress fractures gave any indication that an untoward or violent muscular contraction had preceded his symptoms, whether the onset had been insidious or abrupt. The difference between stress fractures and fractures from muscle violence is more than academic, for the latter may be associated with considerable tissue damage, whereas stress fractures are not.

It was noticed in this series that low fractures tended to be transverse and the higher fractures oblique (Figs. 19 to 22). Between these extremes, at the common site, about six centimetres above the lateral malleolus, the obliquity varied. With only one exception (Fig. 1) the fracture line, whatever the level, ran upwards, inwards and forwards. The frequent absence of periosteal reaction on the inner side of the fibula suggests that the fracture was not always complete and did not involve the medial cortex (Figs. 8, 11 and 12, and 21 to 24). The obliquity is well illustrated in the patient with bilateral stress fractures (Figs. 23 and 24)

FIG. 16

FIG. 17

FIG. 18

With no other injury than making an awkward but violent kick at football the player felt a severe pain in his calf. The initial radiographs showed no abnormality (Fig. 16) but at two and four weeks the callus and fracture line can be seen (Figs. 17 and 18). This is not a stress fracture but a fracture from muscle violence, and soft-tissue damage may be considerable.

FIG. 19 FIG. 20

Figure 19—At one week a fracture line is seen running upwards and inwards. Figure 20 shows the appearance at three weeks: both cortices have been involved. This was among the lowest of the fractures, being 3·5 centimetres from the tip of the malleolus.

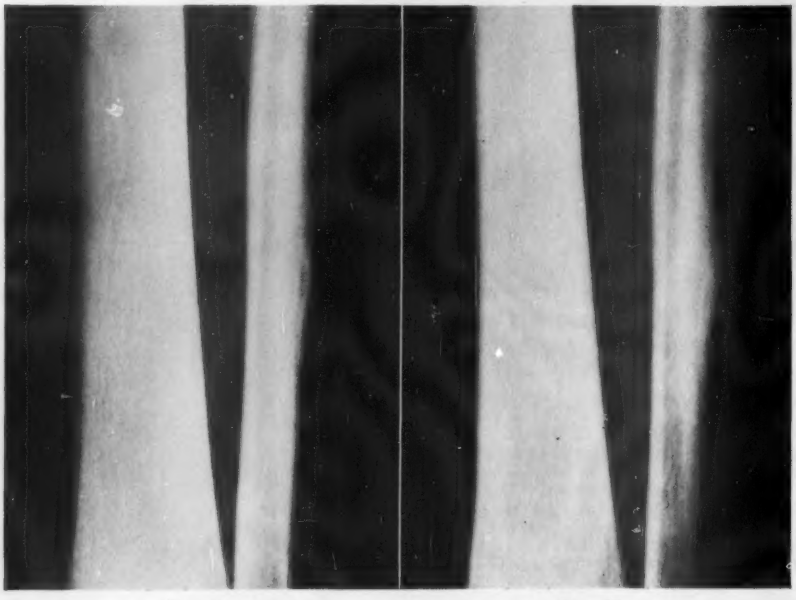

FIG. 21 FIG. 22

A high, long, oblique stress fracture running upwards and medially is shown at four weeks (Fig. 21) and at twelve weeks (Fig. 22). There is nothing to suggest that the medial cortex of the fibula has been involved.

which occurred within a week of each other. He had attempted to continue running with the painful ankle strapped, only to sustain a similar injury on the opposite site.

MECHANISM

We have shown (Table II) that stress fractures of the fibula in athletes occur most commonly from running on hard surfaces. On hard ground a runner tends to land " on his

TABLE IV

SEASONAL INCIDENCE OF STRESS FRACTURES IN FIFTY ATHLETES

Summer		Winter	
April	4	October	5
May	4	November	4
June	3	December	6
July	1	January	5
August	2	February	9
September	1	March	6
	15		35

toes " to protect himself from the jar of each footfall, whereas on a soft track or grass the weight is better distributed over the foot. This may explain the high seasonal incidence in the winter months (Table IV) when road running as a form of training is most common.

FIG. 23 FIG. 24

When one ankle became painful an athlete tried to " run it off " with a result that both fibulae had stress fractures. The upward and medial direction of the fracture line, which involves both lateral and medial cortices, is shown well.

It could be that the strong recurrent and rhythmical contraction of the plantar and long toe flexors transmits, through their origin from the fibula, the extra stress that produces the fracture. To discover the effect of this muscle pull on the fibula, radiographs were taken of the legs of healthy subjects, first with the foot resting, and secondly while they were exerting a strong downward thrust through the ball of the foot. Movement of the leg and foot was prevented by holding them in a wooden frame (Fig. 25).

FIG. 25

By means of a wooden frame adjustable for different leg lengths, radiographs of normal legs were taken with the calf muscles first at rest and then exerting a strong downward thrust. The radiographs were superimposed to show any alteration in the relative positions of the tibia and fibula.

Comparison of the radiographs shows that powerful contraction of the flexor muscles approximates the fibula to the tibia. When these films are superimposed with the tibial shadows corresponding exactly, the altered position of the shaft of the fibula is clearly seen (Fig. 26). It is suggested that in running on the toes there is a " to-and-fro " movement of the fibula, the point of greatest stress being near the inferior tibio-fibular joint, and this is the most frequent site for a stress fracture.

TREATMENT

Without treatment, pain and disability usually continue for three to six months and the athlete who tries to continue training without a period of rest will lose a whole season. With suitable treatment we have found six weeks to be the average time away from athletic activities. Immediate rest from sport is essential; the all too common advice of the trainer to " run it off " results in continued pain, longer incapacity and marked radiographic changes.

Adhesive elastic strapping is applied from the metatarsal heads to below the knee and normal walking is allowed; there is no reason for being off work. This regimen is continued until there is no longer any tenderness on firm pressure over the previously tender area, or pain on compression of the fibula towards the tibia—usually about six weeks from the onset of symptoms. Only then is the strapping discarded and gentle training on a soft surface resumed.

Provided there is no return of symptoms, activity is gradually increased during two or three weeks until the athlete is back to his normal training programme, but running on roads is forbidden.

Other methods of treatment have been tried but found less satisfactory. Both below-knee walking plasters and the continuation of sport, in supportive strapping, aggravated the symptoms and prolonged the disability. There is some indication that thick rubber-soled running shoes reduce the intensity of pain but although it may be a useful prophylactic measure it has not been recommended as a form of treatment.

FIG. 26

FIG. 26

Superimposed radiographs of a normal leg taken in the manner shown in Figure 25. The tibia and lateral malleolus fit exactly, but there is an obvious double shadow of the shaft of the fibula. A powerful contraction of the flexor muscles of the calf has approximated the fibula to the tibia.

SUMMARY

1. An account is given of fifty stress fractures of the fibula which occurred in athletes.

2. The characteristic symptoms, signs and radiological appearances are described, with details of treatment and prognosis.

3. The mechanism of the injury has been suggested on clinical grounds and supported by experimental methods.

We would like to express our gratitude to Mr Philip Wiles and Mr P. H. Newman for their advice and encouragement in both the clinical investigations and the preparation of this report. We also wish to thank Mr M. Turney and other members of the Photographic Department of the Middlesex Hospital for the photographs.

REFERENCES

BURROWS, H. J. (1948): Fatigue Fractures of the Fibula. Journal of Bone and Joint Surgery, **30–B**, 266.

GRIFFITHS, A. L. (1952): Stress Fractures of the Fibula in Childhood. Archives of Diseases of Childhood, **27**, 552.

RICHMOND, D. A., and SHAFOR, J. (1955): A Case of Bilateral Fatigue Fractures of the Fibula. British Medical Journal, **i**, 264.

POST-IRRADIATION FRACTURES OF THE NECK OF THE FEMUR

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There is scanty reference to post-irradiation fractures of the neck of the femur in British surgical literature.

The lesion is nearly always the consequence of radiotherapy given for malignant disease of the pelvic organs—usually for carcinoma of the cervix uteri, occasionally for carcinoma of the corpus uteri or ovary, and rarely for carcinoma of the bladder, vulva or urethra.

In the past there have been a number of errors in diagnosis because of failure to recognise this type of fracture and its premonitory symptoms. Local or referred hip pain, so frequently a symptom of impending fracture, has been attributed to direct spread of the primary disease or to an occult bone metastasis in the lumbar spine, pelvis or femur; consequently, further deep x-ray treatment has not infrequently been given. Sometimes the fracture has been considered to be metastatic in origin and has been treated as such (Bonfiglio 1953, Okrainetz and Biller 1939, Rüther 1953). Occasionally the fracture has been regarded as a simple one, when precipitated in the elderly by a trivial injury.

The first report that we have found in the literature was by Baensch of Leipzig (1927); he described fractures of both femoral necks after irradiation of a carcinoma of the cervix. In 1932 Baensch reported another fracture in a patient irradiated for a malignant ovarian neoplasm. At least 200 of these fractures have since been reported in women, including the series of Dalby, Jacox and Miller (fourteen fractures, 1936), Miller and Folsome (twenty-one fractures, 1938), Peck (twenty-eight fractures, which included those of Dalby, Jacox and Miller 1939), Slaughter (seven fractures, 1942), Gratzek, Holmstrom and Rigler (fourteen fractures, 1945), Kulseng-Hanssen (five fractures, 1946), Stampfli and Kerr (sixteen fractures, 1947), McCrorie (ten fractures, 1950), Kok (eighteen fractures, 1953), Rüther (nineteen fractures, 1953), and Smith (eight fractures, 1954). There have been descriptions of only four such fractures in men. Hight (1941) described fractures of both femoral necks after deep x-ray therapy supplementing a radical amputation of the penis for adenocarcinoma. Smithers and Rhys-Lewis (1945) mentioned one fracture in a patient after radiotherapy for a fibrosarcoma of the thigh. MacDougall, Gibson and Williams (1950) described a fracture with avascular necrosis of the femoral head after irradiation following orchidectomy for a teratoma of the testicle.

In most of the reported cases a metastasis in the femoral neck has been excluded by adequate clinical and radiological follow-up and occasionally by histological examination. All the patients had received cancerocidal doses of irradiation, with or without the use of lateral fields.

At one time the use of lateral portals was thought to be an etiological factor in the production of the fractures, but many have occurred when no such fields have been employed.

PRESENT SERIES

The present series comprises twenty-one fractures of the femoral neck in seventeen patients observed over the past thirteen years. A summary of the cases is presented in Table I. All these patients had been treated for uterine carcinoma by irradiation. Those with carcinoma of the cervix uteri had been treated by radium insertions and deep x-ray therapy. Those with carcinoma of the uterine body had been treated by hysterectomy followed by deep x-ray therapy, with the exception of the patient in Case 2, in whom the tumour was deemed inoperable and deep x-ray therapy was supplemented by the implantation of radon seeds.

The x-ray therapy was administered originally by a six-field technique which included direct lateral fields, the total skin dose being 3,000 r for each field; in later cases this was modified to a four-field technique with the omission of lateral fields, the skin dose being 3,000 r as before. In one instance (Case 2) the fracture was incorrectly attributed to a metastasis in the femoral neck and was subjected to a course of direct irradiation.

All of the survivors have been observed for a minimum of three years since the diagnosis of fracture except for the patient in Case 17 who was well three years after fracture but who was followed for only eleven months radiologically. Two patients died (Cases 2 and 13).

Nearly all the fractures described in the literature have been of the subcapital or high transcervical type, and they were all subcapital in the present series; only a few fractures at a lower level in the femoral neck have been reported.

PATHOLOGY

The material available for histological study was obtained from two patients which came to necropsy (Cases 2 and 13) and from one who was subjected to arthroplasty (Case 16). Although only three of our cases could be studied in this manner, the material they contain covers a wide range of appearances. The time by which fracture preceded the histological examination was one and a half months in Case 16, three months in Case 13, and ten months in Case 2. In addition Case 2 provided unusual material for the study of different degrees of irradiation because the femoral neck had been subjected to direct irradiation after the fracture.

CASE REPORTS WITH HISTOLOGICAL STUDIES

Case 16—Woman aged sixty-three years. In August 1952 this patient was treated by radium implants and deep x-ray therapy for a carcinoma of the cervix uteri, the diagnosis having been confirmed by biopsy. Five months later she began to notice pain in both hips and the pain in the left hip increased in severity. Radiographs showed a subcapital fracture of the neck of the left femur with considerable displacement, and well established osteoarthritic changes in the right hip. An arthroplasty of the left hip was performed, at which the femoral head was replaced by an acrylic prosthesis. The patient made a satisfactory recovery, and one year later a similar operation was performed on the right hip for the chronic arthritis.

Microscopic features—The tissue available for histology comprised four large fragments of the joint capsule, part of the ligamentum teres, the head of the femur which had been separated from the neck by a subcapital fracture, and fragments of the femoral neck removed from the region of the fracture.

The capsule consisted of dense collagen covered by normal synovium, no abnormality being evident apart from fibrous intimal thickening of many arteries with a corresponding reduction in lumen diameter. The same feature was present in the ligamentum teres, a conspicuous example being shown in Figure 1. This change was by no means generalised, and the vascularity of all the tissues examined was within normal limits.

The appearance of the articular cartilage was normal. The cancellous bone lying immediately beneath the cartilage showed no conspicuous abnormality, but loss of bone cells was evident in fields progressing towards the subcapital area. A diminution in the width of many trabeculae was a noticeable feature and this was associated with marked fibrosis of the marrow (Fig. 2). Despite these two features of a degenerative nature there was ample evidence of an active repair reaction. At the fracture site (Fig. 3) a considerable cellular proliferation was evident with deposition of young collagen and early bone formation. Elsewhere there were numerous conspicuous examples of osteoid and new bone deposited on the framework of old trabeculae. This feature is illustrated in Figure 4, which depicts a process of reinforcement of trabeculae which probably antedates the reactions seen in the line of fracture.

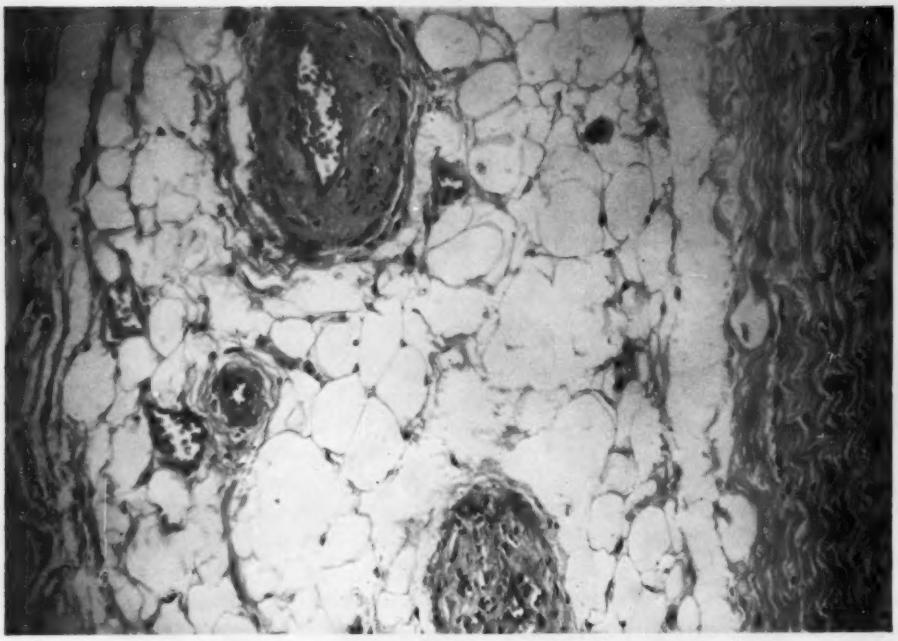

FIG. 1
Case 16—Fibrous intimal thickening of vessels in the ligamentum teres. (×160.)

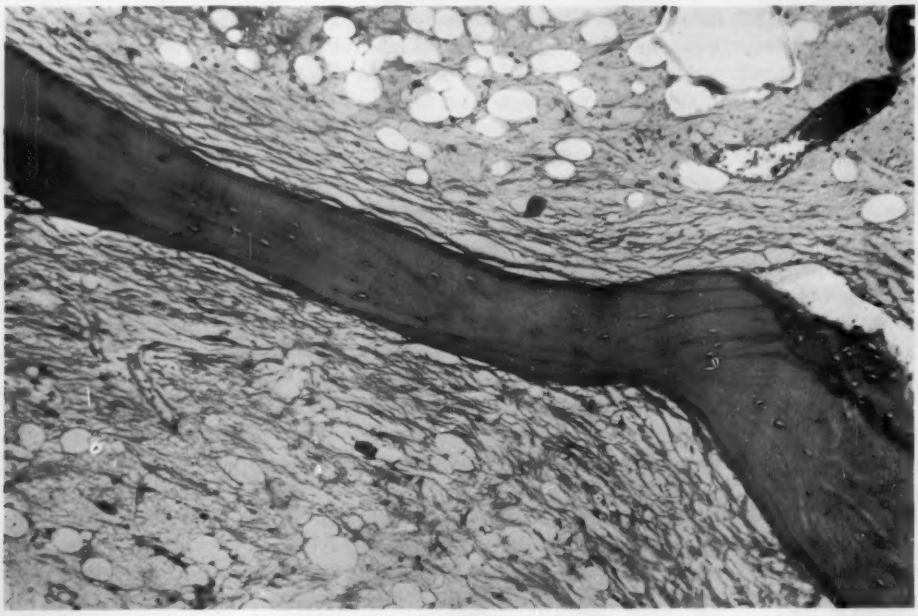

FIG. 2
Case 16—Osteoporosis and fibrosis of the marrow. (×90.)

FIG. 3
Case 16—Active repair reaction at the fracture site. (×95.)

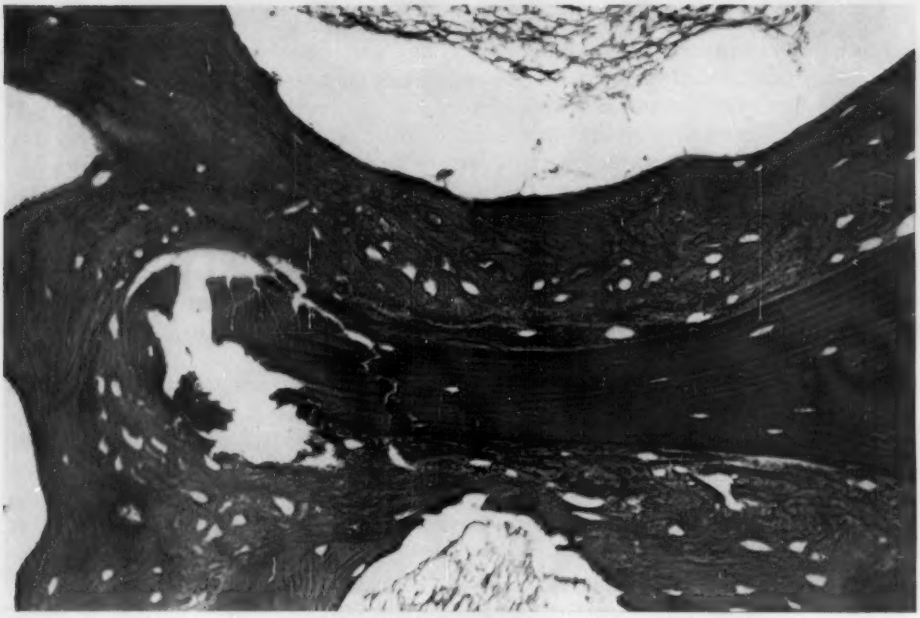

FIG. 4
Case 16—Apposition of new tissue to reinforce osteoporotic trabeculae. (×190.)

The general picture was that of moderately active repair in response to a fracture; extensive osteoid deposits suggested that the bone had previously been subjected to injury. There was no sign of tumour tissue in any of the fields examined.

Case 2—Woman aged seventy-six. This patient was treated by deep x-ray therapy and the insertion of radon seeds for a carcinoma of the body of the uterus which had been found to be inoperable at laparotomy. Radiotherapy was given in August 1947 and five months later she sustained a spontaneous fracture of the neck of the right femur. A further course of deep x-ray therapy was given to the right hip in the belief that the fracture was of metastatic origin. The patient died ten months later. At necropsy the main findings were an irradiated carcinoma of the uterus, post-irradiation vaginitis, pelvic abscess, senile emphysema and a fracture of the right femoral neck.

Microscopic features—The material for histology consisted of the head and neck of the right femur. Sections of the femoral head showed the articular cartilage to be intact and normal in outline. The general architecture of the bone had been greatly altered. In the cancellous area there was a notable decrease in the number and width of bone trabeculae and a relative increase in the area of the marrow spaces, which were largely occupied by fatty tissue. Near the articular cartilage the bone contained a few nucleated cells but elsewhere none was seen. No osteoblasts or osteoclasts were seen in any part of the section.

A striking feature was the apposition to many trabeculae of tissue having the appearance of a framework of coarse fibres (Fig. 5). When viewed by polarised light the structure of this tissue contrasted with the lamellar pattern of the trabeculae and resembled that of coarse woven bone. Figure 6 illustrates a trabecula of bone showing this increment. It can be seen that this trabecula has fractured at the site where it was particularly slender and that on either side of this fracture line incremental tissue is prominent. It is also noteworthy that the apposition of new tissue at the top part of this trabecula restores to its outline a symmetry previously destroyed by osteoporotic change. Perhaps the most striking feature of all is the total absence of cell nuclei.

Similar appearances were to be seen in any field examined. The suggested explanation is that initially osteoporosis developed, probably as a result of the first course of irradiation. A fracture ensued, and at some time subsequently repair processes were initiated. It is further postulated that when the second course of irradiation was administered to the fracture site these repair processes were brought to a complete halt. The sections therefore show what is essentially a petrified phase in the reparative response to loss of bone which has led to fracture. The tissue of repair has neither been resorbed nor has the process of repair been able to continue. For the most part the bone is lifeless, but there are no signs of sepsis. If, in the interests of illustration, one were permitted a fanciful analogy, the picture presented by this slide could be compared to that confronting an archaeologist who unearths a village that had been suddenly overwhelmed by lava: all activity has been arrested but framework structure is preserved because decomposition has not set in.

Sections of the femoral neck were substantially similar to those of the head, especially in the area abutting the fracture. The cortex was thin and there had been great loss of medullary bone. Trabeculae were few and far between and such as remained were widely separated by marrow which was virtually acellular but contained extensive fat spaces. This tissue was not entirely avascular in areas farthest from the fracture line, but the vessels were reduced in size as well as in number.

The general picture was one of widespread necrosis following an abortive attempt to repair a fracture associated with marked osteoporosis. There were no signs of metastatic tumour.

Case 13—Woman aged seventy-one. This patient had been admitted to hospital on many occasions since 1940 with diabetes mellitus. In October 1950 she was treated by radium implants and deep x-ray therapy for a carcinoma of the cervix uteri. Three months later

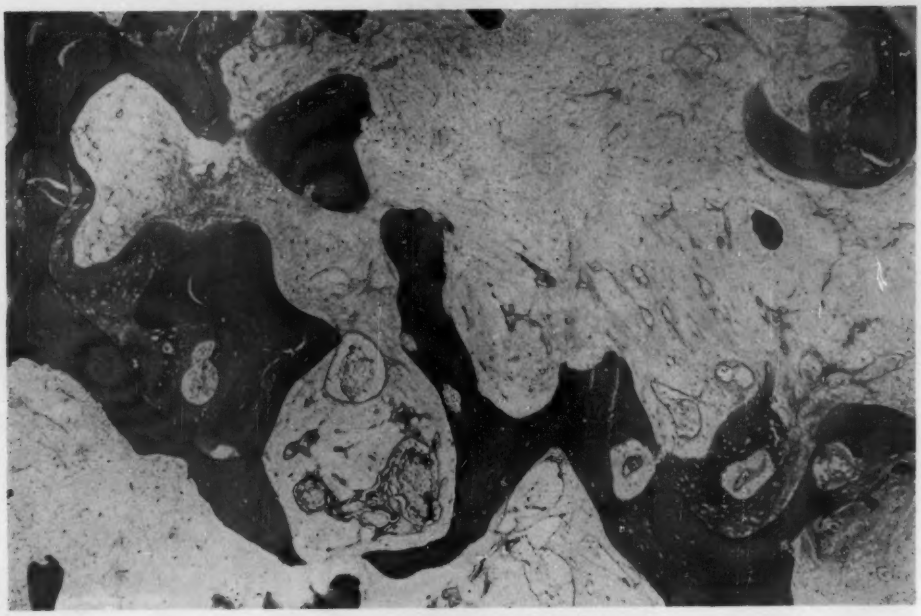

FIG. 5

Case 2—Reinforcement of osteoporotic trabeculae by the apposition of new tissue; acellularity is a striking feature. (×45.)

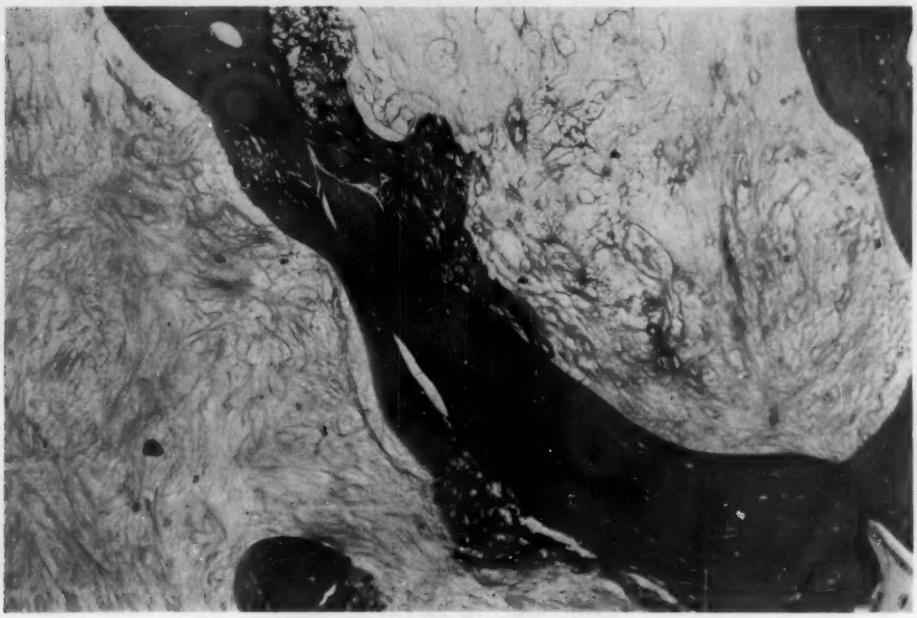

FIG. 6

Case 2—Higher magnification of a trabecula buttressed with coarse fibres; the entire tissue in the field has undergone aseptic necrosis. (×90.)

she began to notice pain in the right hip and right knee which gradually increased in severity. Radiographs in March 1951 showed a subcapital fracture of the neck of the right femur with some displacement, and small circumscribed transradiant areas in the femoral neck. The patient died in diabetic coma in the following month. The findings at necropsy were hypertensive heart disease, widespread arteriosclerosis, cerebral ischaemia, an adenoma of the thyroid gland, irradiated carcinoma of the cervix uteri, and an ununited fracture of the right femoral neck.

Microscopic features—In the region of the fracture an extensive repair reaction was evident. The breach in continuity of the bone had been filled by connective tissue which was rich in cells and blood vessels; within its substance were conspicuous areas of new bone formation. Figure 7 is a low-power field of the area. Under higher magnification, cartilage cells can be

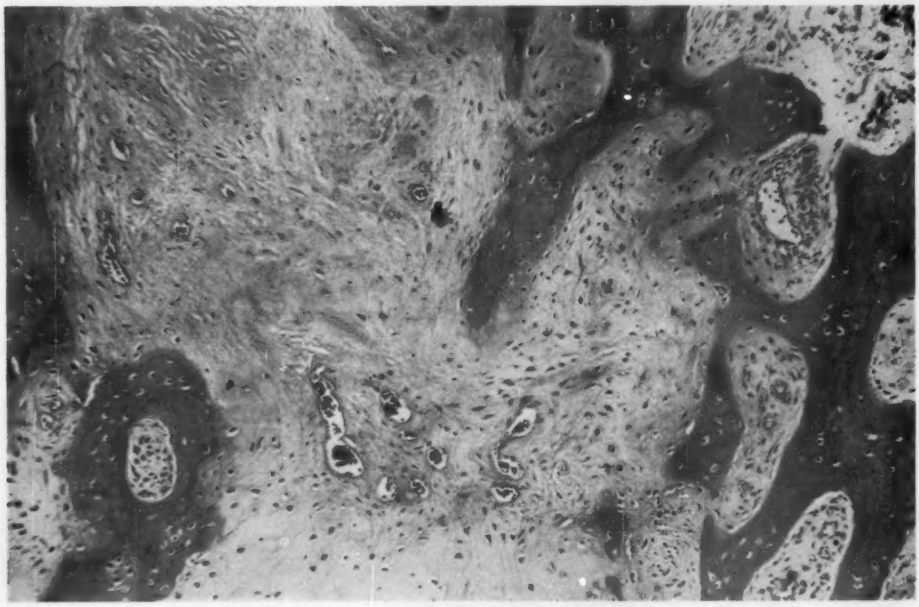

FIG. 7
Case 13—Active repair reaction at the fracture site. (×90.)

seen in relation to forming bone in some areas (Fig. 8), and osteoblasts as well as osteocytes were prominent in the osteogenic zones.

In areas farther from the fracture line nothing like the same cellular activity was seen. Bone trabeculae appeared to be sparse and were of reduced width, while nuclei were absent from many osteocyte spaces and neither osteoblasts not osteoclasts were present; a marked increase in fat cells was a feature of the marrow spaces (Fig. 9). In no instance had the presence of necrotic bone elicited a cellular response.

The general picture was one of an active repair response after fracture of a bone which had previously been the site of a moderate degree of osteoporosis and marked fatty change within the marrow. There was no sign of tumour tissue.

ETIOLOGY AND PATHOGENESIS

There appear to be three fundamental possibilities which, either alone or in conjunction, may account for increased vulnerability of the femoral neck after exposure to radiation.

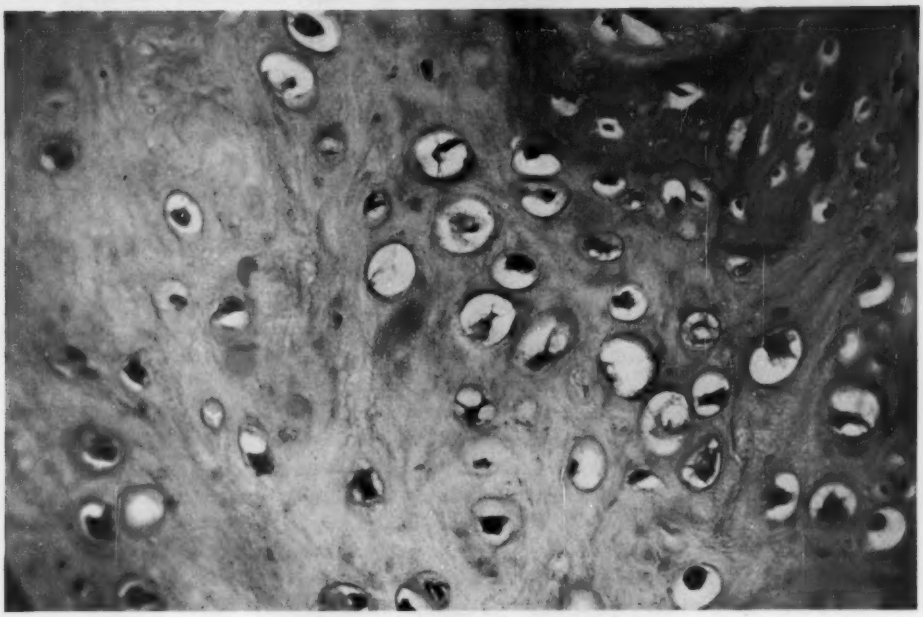

FIG. 8
Case 13—Cartilage cells and bone formation in the region of repair. (×300.)

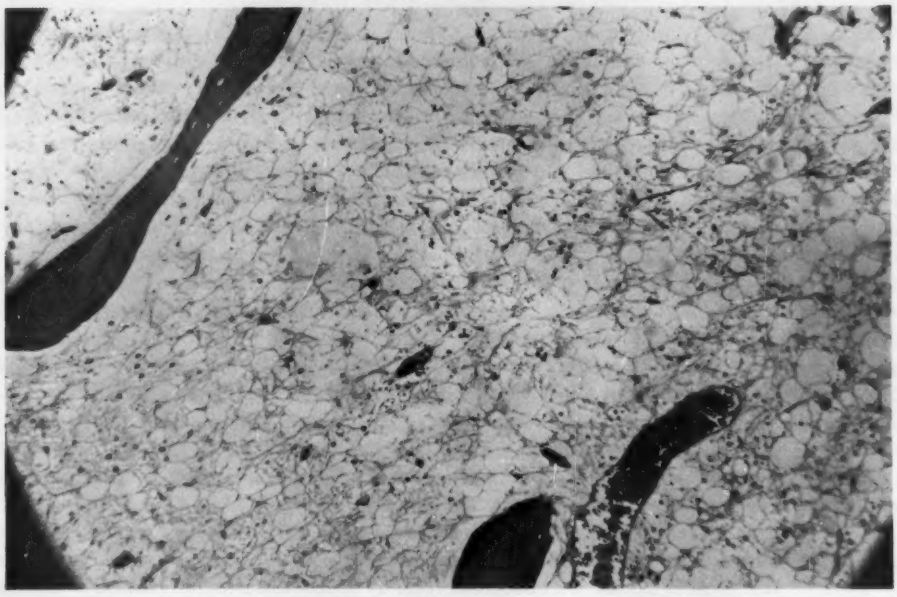

FIG. 9
Case 13—Increase of fat within the marrow spaces and diminution of trabecular bulk, but no evidence of avascularity. (×75.)

Firstly, it is possible that calcified material may be reduced in amount by accelerated resorption; secondly, that even in the absence of exaggerated resorption the normal formative reaction within bone tissues may be inhibited; and thirdly, that the cause of weakening may reside in a deterioration of bone quality rather than a depletion of quantity. The first of these possibilities would be reflected histologically by osteoporosis with a marked increase of osteoclasts; the second possibility might be supported by osteoporotic changes in the absence of osteoblasts but without signs of active resorption; the third possibility would more likely be associated with changes characteristic of osteomalacia than with those typical of osteoporosis.

The effect of irradiation on bone has been widely studied but the exact mechanism whereby the tissue is weakened has yet to be demonstrated conclusively. Regaud (1922) believed that the organic element of bone was affected not only by direct rays but also by secondary radiations reflected from the inorganic components. Ewing (1926) subscribed to this theory of accentuated effect arising from secondary radiation and suggested that the earliest effects were a decrease in the vitality of the bone cells, which might be followed by complete recovery. He recognised four further stages depending on the severity of irradiation, the first of these being a productive osteitis and the second an osteosclerosis marked by increased fragility; this may account for the increased radio-opacity sometimes detected before fracture. The third stage is aseptic necrosis with the formation of sequestra, from which recovery is unlikely; the fourth and most severe stage, seen mainly in the mandible and bones of the face, Ewing described as osteoradionecrosis with superimposed infection. Dahl (1936) claimed that osteoclasts were more resistant to the effects of irradiation than were osteoblasts, and that for that reason the resorption of bone was able to continue while compensatory deposition was brought to a standstill.

The role of vascular changes has been mentioned by several authors. The view has been advanced (Kok 1953) that, in addition to cell damage, a causative factor is impairment of the blood supply from injury to the periosteum. A different appreciation of the significance of vascular changes characterises the theory that irradiation leads to persistent dilation of vessels in the Haversian and Volkmann canals and that this hyperaemia is followed by widening of the canals at the expense of bone. Stampfli and Kerr (1947), who advanced the hyperaemia theory, concluded that osteoporosis secondary to vascular resorption and osteoclastic activity was probably the predisposing cause of irradiation fractures, and that damage to the periosteum, blood vessels and bone cells was another but subordinate factor. The effects of irradiation on bone have often been attributed to vascular damage without supporting evidence. Truelsen (1942) commented on the absence of osteoblasts and osteoclasts and expressed the view that vascular changes within the bone might be responsible; yet he noted no particular changes within the vessels and, indeed, remarked on the preservation of the intima in vessels he examined. Likewise Okrainetz and Biller (1939) attributed irradiation changes to interference with the blood supply although they had observed callus formation, granulation tissue, and innumerable small vessels at the site of fracture in the case which they reported. There can be no doubt that a sufficient intensity of radiation will destroy both bone and blood supply; but the possibility exists that irradiation sufficient to render bone unnaturally brittle may inflict no damage on vascular elements. The material studied in this series lends support to this belief, in spite of the fact that in Cases 4 and 15 healing was followed by considerable resorption of the femoral head.

The fact that healing commonly occurs in these fractures, as noted by many of the authors quoted above, cannot easily be reconciled with the concept that vascular damage has been sustained. The expectation of a healing response is of immense importance in assessing treatment and prognosis. In this connection the danger of attributing the fracture to metastatic growth must be reiterated. In none of the cases examined histologically was tumour tissue found within the bone, and in none of the cases of our entire series can the fracture be

attributed to metastases. Kalayjian (1938) described bilateral subcapital fractures in a woman treated by deep x-ray therapy for carcinoma of the cervix. He reported this as an unusual instance of bilateral metastases; the case history, however, conforms strikingly with those of patients suffering from irradiation fractures. It is worth remembering that metastases to bone from uterine carcinoma are rare; and that the type of fracture described in this paper is an established clinical entity.

The effects of irradiation on bone marrow were comprehensively described by Bloom (1948), who observed that haemopoietic cells were destroyed but that macrophages, reticular cells and fat cells were relatively radio-resistant. Thus the haemopoietic element becomes replaced by dilated sinuses and a fatty, gelatinous marrow. After severe or prolonged irradiation the gelatinous marrow is said to be replaced sometimes by an atypical fibrous bone. This was not exemplified in any of the material examined in this series; however, the destruction of specialised cells and their replacement by fatty material was a constant feature in all the slides studied.

On the basis of the three cases studied histologically it is possible to advance the following hypothesis concerning the pathogenesis of these fractures. There is evidence that the fracture is preceded by loss of trabecular bulk. Our material confirms the view of Bonfiglio (1954) and others that osteoporosis is a predominant feature. No signs are seen to suggest that this is the consequence of osteoclastic activity. Destruction of cellular elements of the osseous tissue, as well as fatty change within the marrow, occurs constantly. It can be said with certainty that obliteration of the blood supply is not responsible for the bone changes. This is borne out by the fact that in each of the cases studied fracture was followed by a repair response that would not have been possible had the blood supply been materially impaired. Watson-Jones (1952) pointed out that in no fracture of the femoral neck is the blood supply to the femur more seriously endangered than in those of the subcapital type. All three of these fractures were subcapital, and yet in all three repair indicates preservation of the blood supply. This suggests the possibility that the meagre blood supply of this area might have been enhanced as a result of irradiation.

The above hypothesis is applicable to fractures in which the severity of irradiation is not such that complete cellular destruction is brought about. Case 2 shows that direct and intensive irradiation will arrest repair and lead to complete necrosis of bone. Whether the femoral neck can be exposed to such intensity as an indirect result of irradiation to pelvic organs cannot be deduced from the material studied.

CLINICAL FEATURES

The clinical features in our cases conformed with those of other published reports.

Incidence—The incidence in this series is unknown because some of the patients treated by radiotherapy for intrapelvic disease during the period covered by our investigation have not been traced. In the cases reported by Dalby *et al.* (1936) the incidence was 2·1 per cent. Kok (1953) assessed the incidence as 1·45 per cent, Stampfli and Kerr (1947) 0·87 per cent and Peck (1939) 2·7 per cent. Vaughan (1955) reported an incidence of between 0·1 and 3·2 per cent of fractures of the femur and pelvis after pelvic irradiation.

Sex—In our series all the patients were women and reference has already been made to the rarity of the fracture in men.

Age—The patients are usually in the sixth or seventh decade, and fifty-five to sixty years is the commonest age group. However, there is a variation within fairly wide limits; the youngest reported patient was thirty-four years of age (Gratzek *et al.* 1945, Stampfli and Kerr 1947) and the oldest seventy-nine.

In the present series the average age was sixty-one years; the youngest patient was thirty-eight and the oldest seventy-six.

TABLE I

CLINICAL DETAILS OF SEVENTEEN PATIENTS WITH FRACTURES OF THE NECK OF THE FEMUR AFTER IRRADIATION

Case number	Age	Site of primary disease	Interval between radiotherapy and diagnosis of fracture *years*	*months*	Mode of onset	Treatment	Result	Remarks
1	64	Cervix	3	4	Pain for two months	Walking caliper	Bony union	Caliper discarded; walks well without any aid
2	76	Body of uterus	0	7	Spontaneous	Palliative	Died	Died ten months after diagnosis of fracture
3	54	Cervix	9	5	Pain for two months	Walking caliper	Bony union	Caliper discarded; Walks well with one stick
4	76	Cervix	0	6	Pain for one month	Palliative	Necrosis and collapse of femoral head	Ambulant, but with a painful hip. Walks with the aid of two sticks
5	62	Body of uterus	0	5	Spontaneous	Traction for twelve weeks, followed by walking caliper	Bony union	Caliper discarded; walks well with the aid of one stick
6	60	Cervix	0	8	Pain for three months (R. and L.)	Traction (R. and L.) followed by walking caliper L. only	Bony union (R. and L.)	Bilateral fractures. Caliper discarded; walks well with the aid of one stick
7	38	Cervix	1	8	Pain for six months (R. and L.)	Palliative	Bony union R.; incomplete bony union L.	Bilateral fractures. Walks well without any aid
8	50	Cervix	1	6	Pain for four months	Palliative	Bony union	Walks well without any aid
9	65	Cervix	2	5	Pain for one year and three months (R.); spontaneous (L.)	Palliative	Bony union (R. and L.)	Bilateral fractures. Walks well without any aid
10	65	Cervix	1	6	Pain for three months	McMurray osteotomy	Bony union	Walks well without any aid
11	52	Body of uterus	1	4	Pain for three months	Traction for twelve weeks followed by graduated return to full weight bearing	Bony union	Walks well with aid of one stick
12	65	Body of uterus	0	9	Pain for two months followed by minor trauma	McMurray osteotomy	Incomplete union of fracture; complete union of osteotomy	Ambulant, but with painful hip; walks with the aid of two sticks
13	71	Cervix	0	5	Pain for two months	Palliative	Died in diabetic coma	Died within two months of diagnosis of fracture
14	47	Cervix	1	9	Pain for five months	Traction for twelve weeks, followed by walking caliper	Bony union	Caliper discarded; walks well with the aid of one stick

TABLE I—*continued*

Case number	Age	Site of primary disease	Interval between radiotherapy and diagnosis of fracture *years*	*months*	Mode of onset	Treatment	Result	Remarks
15	55	Body of uterus	1	5	Pain for three months	Walking caliper	Necrosis and collapse of femoral head	Walks with a raised boot but without other aid
16	63	Cervix	0	6	Pain for one month	Arthroplasty of hip with insertion of acrylic head	Satisfactory	—
17	67	Cervix	1	6	Pain for six months (L.); pain for one month (R.)	Traction for twelve weeks (R. and L.) followed by graduated return to weight bearing	Not united (R. and L.) eleven months after diagnosis of fractures. No radiological follow-up since	Bilateral fractures. Walks with aid of one stick three years after diagnosis of fractures

Symptoms and signs—The vast majority of patients complain of pain which precedes by several weeks or several months any other evidence, either clinical or radiological, of actual fracture. There is an interval, varying from a few months to several years after irradiation, before the onset of this pain. In our cases this interval averaged eighteen months, the shortest being three months (Case 13) and the longest nine years and three months (Case 3). These intervals are comparable to those noted in other published reports, but the long interval of nine years and three months is exceptional. Nevertheless the clinical and radiological features of this case together with the course of the disease were so typical in all other respects that it could not justifiably be excluded. Bonfiglio (1953) recorded an interval of six years and four months between fracture and irradiation in one of his cases.

The pain may be located in the hip or referred to the knee; it may even take the form of sciatica. At the outset it is seldom incapacitating and may be noticed only when the patient stands or walks. Later it becomes slowly and increasingly more pronounced and then weight bearing may either be accompanied by considerable limp or become impossible.

In some patients there is, ultimately, a sudden, acute exacerbation of pain: in others, no such exacerbation occurs and the disability may remain surprisingly slight; in a few the fracture is precipitated by a trivial injury which has been preceded by several weeks or months of discomfort. In some patients the fracture is essentially spontaneous, there being no prodromal symptoms.

In most reported series there have been a few patients with bilateral fractures and in ours there were four (Cases 6, 7, 9 and 17) (Fig. 10). When the fracture is bilateral the symptoms and signs of each fracture may arise concurrently or there may be an interval of months, or occasionally of years, before the second hip attracts attention. Furthermore, the mode of onset in each hip is not necessarily the same. The presenting features in our four cases are given in Table I, and they accord with the clinical findings of other writers.

In the usual case with a prodromal period of pain, physical examination of the hip is negative at the outset. Later, there may be pain at the extremes of movement and, still later, the signs of coxa vara may slowly become evident. A remarkable degree of voluntary control is often well maintained even when the fracture has become clearly evident in radiographs and when a marked degree of coxa vara is also present.

When the fracture is spontaneous, follows trivial trauma or is heralded by an acute exacerbation of the premonitory pain, the physical findings are those of any new adduction fracture of the neck of the femur. The amount of displacement is variable in such cases and there is loss of voluntary control.

Radiographic appearances—The earliest radiological evidence described of an impending fracture is an irregular transverse line of increased density in the femoral neck (Gratzek *et al.* 1945, Stampfli and Kerr 1947, MacDougall *et al.* 1950, Kok 1953). The position of this line in the femoral neck is subcapital or high transcervical. Small, scattered, circumscribed areas of increased transradiance may also be seen in the neck of the femur. The foregoing appearances are by no means invariably present and, indeed, there is frequently no discernible radiological abnormality before the appearance of the fracture.

When the fracture is incomplete the line of separation first becomes apparent at the lateral margin of the femoral neck. When the fracture is complete the fracture line is not so clearly defined as that of an ordinary fracture. There is usually coxa vara of variable degree.

Smith (1954) drew attention to what he believed to be a characteristic deformity. It is a coxa vara without the lateral angulation of the head on the neck; in a number of his cases there was little or no lateral angulation to be seen in the lateral radiographs. This feature has also been noted in some of our patients in whom the onset was entirely insidious.

Healing of the fracture is frequently associated with considerable sclerosis at the fracture site and in the adjacent bone, a finding that contrasts with the radiographic appearance of a simple healed fracture of the femoral neck (Fig. 11).

DIAGNOSIS

The diagnosis can be made confidently if the condition is borne in mind and the clinical picture is typical. Otherwise, the diagnosis may have to remain provisional until confirmed by the subsequent course or by the histological examination of biopsy material such as became available in Case 16.

TREATMENT

There is no simple, pre-eminent line of treatment and the methods available are the same as those for simple fractures of the femoral neck; there are recorded instances of successful results obtained from nearly all such forms of treatment, including bone grafting. Nevertheless, the problem is coloured by four additional factors. First, the diagnosis cannot always be made initially with certainty. Secondly, the fracture may have been present for some time before it is suspected and before the patient comes under surgical care; healing then may already be progressing, usually with a coxa vara which is irreducible by closed methods. Thirdly, the expectation of life of the elderly patients is further reduced by the presence of malignant disease and this circumstance favours a method of treatment which will give early restoration of function. Fourthly, the state of the primary malignant disease and its prognosis has to be taken into consideration when deciding on the management of the hip lesion.

The treatment of the cases under review has not been carried out, therefore, on any definite plan and a few had already been treated elsewhere for their fractures. The methods of treatment used are indicated in Table I.

One patient was treated by replacement of the femoral head by an acrylic prosthesis.

Two patients were treated by McMurray osteotomy, five by continuous traction, three by walking calipers. The remaining six patients received palliative treatment. This consisted of a period in which weight bearing on the affected hip was prohibited, followed by physiotherapy and a graduated return to full weight bearing.

A substantial number of the reported patients received only palliative treatment and some refused treatment. Many have, seemingly, regained remarkably good function with fibrous or bony union of the fracture. In our series three such patients (Cases 7, 8 and 9) ultimately were able to walk well without pain and without the aid of a stick.

FIG. 10

Case 6—Bilateral fracture, with marked degree of displacement on the right side and a mild degree on the left side.

FIG. 11

Same case, showing bony union on the right side with sclerosis at the fracture site and coxa vara.

None of the fractures in the present series has been treated by a Smith-Petersen nailing operation. The number of nailing operations in the literature has been small, but the incidence of avascular necrosis in the femoral head or of other complications does not seem to have been high.

PROGNOSIS

The prognosis is good and compares favourably with that of simple adduction fractures of the femoral neck. Many of the fractures described in the literature have united by bone or have shown progress towards bony union. Some patients have been able to walk with a stable hip although bony union has not been confirmed on inspection of the radiographs. Some fractures have united in spite of considerable unreduced deformity and others despite complete absence of immobilisation.

In this series twelve of the fractures have united by bone and two have incomplete bony union. There were two cases of necrosis and collapse of the femoral head. Two patients with unilateral fractures died. One of the patients with a unilateral fracture was treated by an arthroplasty of the hip. One patient, with a bilateral fracture, was not followed up for longer than eleven months but bony union may have subsequently occurred as it progresses very slowly and may take well over a year before it becomes complete.

SUMMARY AND CONCLUSIONS

Twenty-one post-irradiation fractures of the femoral neck are reported in seventeen patients who had been treated by radiotherapy for carcinoma of the uterus.

The clinical and radiological appearances are described and the diagnosis, prognosis and treatment of this type of fracture are discussed.

Histological material has been studied in three cases.

It is concluded:

1. That there is a characteristic clinical picture in which premonitory pain is of paramount significance.
2. That when the diagnosis is considered, the likelihood of irradiation damage should take precedence over the remote possibility of metastatic invasion.
3. That the disability varies, but in general the prognosis is favourable.
4. That there is no specific line of treatment applicable to these fractures.
5. That avascularity is not the underlying cause of this lesion.

We are greatly indebted to Dr L. H. Walter, Department of Radiotherapy, Hammersmith Hospital, for her permission to investigate these patients, all of whom were under her care, and for her assistance with the analysis of their case records.

Some of the patients have been treated for their fractures by orthopaedic surgeons in other hospitals, and two have been afforded hysterectomy by gynaecologists elsewhere. We are grateful to these surgeons for documents made available to us through Dr Walter.

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REFERENCES

BAENSCH, W. (1927): Knochenschädigung nach Röntgenbestrahlung. Fortschritte auf dem Gebiete der Röntgenstrahlen, **36**, 1,245.

BAENSCH, W. (1932): Über Spontanfrakturen des Schenkelhalses nach Röntgenbestrahlung. Röntgenpraxis, **4**, 716.

BLOOM, M. A. (1948): Bone Marrow. *In* Histopathology of Irradiation. Edited by W. Bloom. Chapter 6. New York, Toronto, London: McGraw-Hill Book Company, Inc.

BONFIGLIO, M. (1953): The Pathology of Fracture of the Femoral Neck Following Irradiation. American Journal of Roentgenology, **70**, 449.

DAHL, B. (1936): La théorie de l'ostéoclasie et le comportement des ostéoclastes vis à vis du bleu trypan et vis à vis de l'irradiation aux rayons X. Acta Pathologica et Microbiologica Scandinavica. Supplementum 26, 234.
DALBY, R. G., JACOX, H. W., and MILLER, N. F. (1936): Fracture of the Femoral Neck Following Irradiation. American Journal of Obstetrics and Gynecology, **32,** 50.
EWING, J. (1926): Radiation Osteitis. Acta Radiologica, **6,** 399.
EWING, J. (1926): Tissue Reactions to Radiation. American Journal of Roentgenology, **15,** 93.
GRATZEK, F. R., HOLMSTROM, E. G., and RIGLER, L. G. (1945): Post-irradiation Bone Changes. American Journal of Roentgenology, **53,** 62.
HIGHT, D. (1941): Spontaneous Fracture of the Femoral Neck Following Roentgen-ray Therapy Over the Pelvis. Journal of Bone and Joint Surgery, **23,** 676.
KALAYJIAN, B. S. (1938): Bilateral Subcapital Fractures of the Femurs Following Carcinoma of the Uterus. American Journal of Roentgenology, **40,** 383.
KOK, G. (1953): Spontaneous Fractures of the Femoral Neck after the Intensive Irradiation of Carcinoma of the Uterus. Acta Radiologica, **40,** 511.
KULSENG-HANSSEN, K. (1946): Fracture of the Femoral Neck Following Roentgen Irradiation for Cancer of the Uterus. Acta Radiologica, **27,** 531.
MACDOUGALL, J. T., GIBSON, A., and WILLIAMS, T. H. (1950): Irradiation Necrosis of the Head of the Femur. Archives of Surgery, **61,** 325.
MCCRORIE, W. D. C. (1950): Fractures of the Femoral Neck Following Pelvic Irradiation. British Journal of Radiology, **N.S. 23,** 587.
MILLER, N. F., and FOLSOME, C. E. (1938): Carcinoma of the Cervix. A Consideration of Certain Problems Associated with its Control. American Journal of Obstetrics and Gynecology, **36,** 545.
OKRAINETZ, C. L., and BILLER, S. B. (1939): Fracture of the Neck of the Femur Complicating Roentgen Therapy of Ovarian Cancer. American Journal of Roentgenology, **42,** 883.
PECK, W. S. (1939): Fractures of the Femoral Neck Following Pelvic Irradiation. University Hospital Bulletin, Ann Arbor, **5,** 33.
REGAUD, C. (1922): Sur la sensibilité du tissu osseux normal vis-à-vis des radiations X et Y et sur le mécanisme de l'ostéo-radio-nécrose. Comptes Rendus Hebdomadaires des Séances et Mémoires de la Société de Biologie, **87,** 629.
RÜTHER, E. (1953): Spontanfrakturen des Schenkelhalses und Schambeines nach Röntgen-Therapie maligner gynäkologischer Erkrankungen. Geburtshilfe und Frauenheilkunde, **13,** 624.
SLAUGHTER, D. P. (1942): Radiation Osteitis and Fractures Following Irradiation. American Journal of Roentgenology, **48,** 201.
SMITH, F. M. (1954): Fracture of the Femoral Neck as a Complication of Pelvic Irradiation. American Journal of Surgery, **87,** 339.
SMITHERS, D. W., and RHYS-LEWIS, R. D. S. (1945): Bone Destruction in Cases of Carcinoma of the Uterus. British Journal of Radiology, **N.S. 18,** 359.
STAMPFLI, W. P., and KERR, H. D. (1947): Fractures of the Femoral Neck Following Pelvic Irradiation. American Journal of Roentgenology, **57,** 71.
TRUELSEN, F. (1942): Injury of Bones by Roentgen Treatment of Cancer of the Uterine Cervix. Acta Radiologica, **23,** 581.
VAUGHAN, J. (1955): Radiation Effects on Bone. Journal of Bone and Joint Surgery, **37–B,** 345.
WATSON-JONES, Sir R. (1952): Fractures and Joint Injuries. Fourth edition, Vol. 1. Edinburgh and London: E. & S. Livingstone Ltd.

INDUCED HYPOTENSION IN ORTHOPAEDIC SURGERY

Hexamethonium Bromide (C_6) in 407 Orthopaedic Operations

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Since Enderby (1950) first described the use of pentamethonium for a temporary reduction of blood pressure in order to prevent excessive bleeding during surgical operations, only one report of the application of methonium compounds in orthopaedic surgery has appeared (Steven and Tovell 1954). A review of figures concerning blood loss and post-anaesthetic progress in 407 operations performed with the aid of hexamethonium bromide may therefore be of interest. The period under review is the first four years of its use at the Orthopaedic Department, Royal Infirmary, Edinburgh.

TABLE I

NATURE OF OPERATION

Region	Operation	Number	Total
Hip	Femoral head replacement	177	
	Cup arthroplasty	45	
	Fusion	37	
	Disarticulation	3	
	Girdlestone	2	
	Hindquarter amputation	1	
	Acrylic replacement of upper third femur	1	266
Femur	Plating, bone graft, etc.	19	
	Intramedullary nail	13	32
Shoulder	For recurrent dislocation	21	
	Fusion	6	
	Acrylic replacement of upper third humerus	3	
	Disarticulation	1	
	Miscellaneous	7	38
Humerus	Open reduction upper end	6	
	Intramedullary nail	2	8
Spine	Fusion	58	
	Excision of sacrum	3	
	Miscellaneous	2	63
Total number of operations			407

The reason for inducing hypotension was to prevent the considerable loss of blood commonly associated with certain orthopaedic operations which tends to make their execution difficult and may be a risk to the patient. Ischaemia of the surgical wound was achieved by lowering the arterial and pulse pressures by ganglionic blockade and elevating the part to be operated upon so that, as far as possible, it was higher than the rest of the body. Regions such as the lower limbs, which are most capable of storing the blood drained from the field of operation, must be in a dependent position. The lungs can store large quantities of blood but they are not suitable for this purpose because pulmonary engorgement greatly reduces vital capacity.

Types of operation and sex and age distribution of the patients are detailed in Tables I and II.

Dosage of hexamethonium bromide—The dose most frequently used in this series was 50 milligrams. This was reduced in the old and frail, in patients who had undergone prolonged immobilisation, and when unfavourable postures were planned. A number of patients required up to 100 milligrams, but this was rarely exceeded and 150 milligrams was the largest dose employed. It should be remembered that less hexamethonium bromide will be required to produce an adequate degree of hypotension in a deeply anaesthetised patient than in one under light anaesthesia.

Once ganglionic blockade was established, it was found that further administrations prolonged rather than intensified hypotension. The duration of depression of systolic pressure below 80 millimetres Hg. varied between 10 and 120 minutes but was most commonly in the order of sixty minutes. The time that elapsed before blood pressures returned to the pre-operative level was usually between six and twenty-four hours, being longer in previously hypertensive patients.

In most cases the systolic pressure fell to between 50 and 65 millimetres Hg., while diastolic pressure was often difficult to assess accurately. It was necessary to lower the systolic

TABLE II

SEX AND AGE

Age (*years*)	Male	Female	Total
10–20	9	2	11
21–30	27	17	44
31–40	29	20	49
41–50	47	33	80
51–60	36	51	87
61–70	36	53	89
71–80	19	24	43
81–90	—	4	4
Total	203	204	407

pressure to about 65 millimetres Hg. before a good ischaemic result was obtained, except in old patients in whom a pressure of between 70 and 80 millimetres Hg. at times produced satisfactory operating conditions. Vasomotor resistance to hexamethonium bromide was met in a few cases but was not, as has been claimed, confined to the young. On occasions, systolic pressures of between 20 and 40 millimetres Hg. were observed, but while a safe posture and adequate tissue oxygenation obtained, no adverse effects on the patient were noted.

BLOOD TRANSFUSION

Table III indicates the total amount of blood transfused in the series under review. It will be noted that one patient was given 15 milligrams of methylamphetamine hydrochloride (methedrine) during operation. This was done by an assistant who had taken over supervision for a time and considered the blood pressure too low, though in all other respects the patient's condition was satisfactory. The injection was followed by haemorrhage requiring transfusion of one litre of blood.

Table IV shows the average amounts of blood transfused in two groups of patients undergoing comparable operations, one with induced hypotension (author's series) and one

without (Kern 1952). The difference is less considerable in the cases of arthrodesis mainly because a number of these procedures were carried out in the supine position, which does not favour the draining of blood from the surgical site. Fairly typical is the record of a man, aged seventy, who suffered from osteoarthritis of both hips. His general condition was good and his blood pressure 150/90 millimetres Hg. When the left femoral head was being replaced by an acrylic prosthesis hypotension was not induced, bleeding was considerable and 1,080 millilitres of blood had to be transfused. Five months later a similar procedure was carried out on the right side and on this occasion hypotension was induced with 50 milligrams hexamethonium bromide. Blood loss was less than 50 millilitres and post-operative progress uneventful.

TABLE III

BLOOD TRANSFUSION IN 407 CASES OF INDUCED HYPOTENSION WITH HEXAMETHONIUM BROMIDE

Indications	Number of cases	Quantity per case (*millilitres*)	Total (*millilitres*)
Low pre-operative haemoglobin	6	540	3240
	1	1080	1080
Blood loss from:			
(*a*) Inadequate reduction of B.P.	5	540	2700
	2	1080	2160
	2	1620	3240
(*b*) Insufficient elevation of site	1	540	540
	2	1080	2160
	1	1620	1620
(*c*) Methylamphetamine hydrochloride during operation	1	1080	1080
Prophylactic in extensive operations	3	540	1620
	1	1080	1080
Reactionary haemorrhage	9	540	4860
	3	1080	3240
None	370	None	None
Total	407	—	28,620

MORBIDITY

Reactionary haemorrhage—Table III shows that there were twelve cases of reactionary bleeding which required replacement of blood. Some surgeons have gained the impression that the incidence of post-operative haematoma has been higher in this series than after similar procedures performed without ganglionic blockade. However, accurate records of this complication in a control series are not available and a reliable comparison is therefore not possible. Avoidance of reactionary bleeding after operations carried out with the aid of induced hypotension will depend on: 1) meticulous haemostasis at operation; 2) gradual rise of blood pressure (if vasopressor drugs are required, they should be used in small doses); and 3) pressure-bandaging after operation.

Meteorism—Meteorism, the commonest post-operative complication in the series, occurred after twenty-six of 266 operations on the hip and after eight of fifty-eight spinal fusions; it was not observed after other procedures. Its incidence was limited to patients who were immobilised in the supine position after operation. In six of the thirty-four cases the condition was severe and took six or more days to respond to treatment by drip and gastric suction;

in the remaining twenty-eight the meteorism was moderate in degree and in four or five days it was corrected by flatus enema and occasionally by sympathomimetic drugs.

Kern (1952) did not report any meteorism in the comparable operations of his series which were performed without induced hypotension and the question therefore arises whether in the cases under review hexamethonium may have been a causal factor. The likelihood of this is supported by the observations of Kay and Smith (1950, 1951) and of Douthwaite and Thorne (1951), who noted in patients given hexamethonium bromide delayed emptying and diminished peristalsis of the stomach and dilation and immobility of the duodenum and upper jejunum, lasting about six hours. On the other hand, reports of the use of this drug during various surgical interventions other than operations on the spinal column and hip joint contain no record of meteorism or ileus.

The incidence of meteorism is known to be high in patients nursed in a posterior plaster shell or hip spica, and Professor Norman Dott (1955) advises turning of the patient as a cure. The explanation of this predisposition is that in the supine posture the third part of the duodenum is readily obstructed by the overlying root of the mesentery, particularly when the small gut is full. Since the end of the period under review four patients have developed meteorism but improved promptly after being placed in the prone position.

TABLE IV

AVERAGE QUANTITIES OF BLOOD TRANSFUSED IN COMPARABLE OPERATIONS ON HIP JOINT

Operation	336 cases without induced hypotension (Kern)	262 cases with induced hypotension (Holmes)
Femoral head replacement	743 millilitres (179 cases)	27 millilitres (177 cases)
Cup arthroplasty . .	945 millilitres (106 cases)	48 millilitres (45 cases)
Arthrodesis . . .	770 millilitres (49 cases)	102 millilitres (37 cases)
Disarticulation . .	2650 millilitres (2 cases)	180 millilitres (3 cases)

Thrombophlebitis and pulmonary infarction—Eleven cases of thrombophlebitis, six of which led to pulmonary infarction, occurred in this series. One additional case of infarction exhibited no previous signs of venous thrombosis. Six of these seven patients had only moderate symptoms; the remaining one suffered a massive fatal embolus.

A period of very low blood pressure may be thought to predispose to venous thrombosis, but a comparison of the incidence in the present series and that of Kern (1952) does not suggest this (Table V). It may be of interest to mention the case of one patient, a man aged forty-three, who suffered from osteoarthritis of both hips. Acrylic replacement of the right femoral head was carried out without induced hypotension at another hospital. Severe thrombophlebitis of the contra-lateral leg developed with pain and swelling, the latter lasting many weeks. After a similar operation on the left side nine months later with the aid of C_6 no thrombosis or other complication supervened though there was still some residual swelling of the left leg dating from the thrombophlebitis which followed the first operation. Table V includes only eight cases of thrombophlebitis and six of infarction, the other three cases being excluded because they occurred after spinal fusion, an operation that does not figure in Kern's series.

Thrombophlebitis frequently follows operations on the hip joint and femur. However, the difference in incidence between the comparable series, shown in Table V, recalls the possibility that intravenous transfusion may be responsible for initiating venous thrombosis.

Post-operative mental confusion—This complication was observed in nine patients, all over seventy years of age. Each had a pre-operative history of periodic confusion occurring particularly at night. Six recovered completely and in one the condition was more marked after operation. The remaining two patients died of congestive cardiac failure. In one, confusion began thirteen days after operation, which makes it unlikely that the period of induced hypotension was responsible in this case. It is believed that a pre-operative history of confusion and disorientation or cerebral thrombosis should be regarded as a contra-indication to the use of hexamethonium bromide.

Retention of urine—Difficulty of micturition to a varying degree was experienced by twenty-five patients. In twelve it followed the operation of spinal fusion. Furthermore, only the patients who were nursed in a posterior shell were affected and females more often than males. It appears that retention was due to posture rather than the use of any particular drug. After operations other than spinal fusion the incidence was about 3 per cent.

TABLE V

INCIDENCE OF THROMBOPHLEBITIS AND PULMONARY INFARCTION

	After 395 operations on hip and femur *without* induced hypotension (Kern)	After 298 operations on hip and femur *with* induced hypotension (Holmes)
Thrombophlebitis .	48 (12%)	8 (under 3%)
Pulmonary infarction	14 (3 died)	6 (1 died)

MORTALITY

Total mortality for this series was ten (2·5 per cent). Six patients, three men and three women, died of congestive cardiac failure. Their ages ranged from sixty-five to eighty-two years, all had had operations on the hip joint and all suffered before operation from some degree of myocardial degeneration and pulmonary congestion. Death occurred at four to thirty days after operation. It has been suggested that hexamethonium bromide may be responsible for precipitating congestive cardiac failure in this type of patient. However, the work of Kelley *et al.* (1953) and of Burch (1955) indicates that C_6 has a beneficial effect by reducing venous pressure markedly and effecting an " impressive improvement " in the clinical picture in cases of established congestive failure. A recent study by Bromage (1956) shows that hypotension induced by ganglion-blocking drugs or sympathetic blockade increases vital capacity considerably in patients suffering from pulmonary congestion.

One patient, a woman of seventy-four, died of cerebral thrombosis forty-three days after femoral head replacement, and another, a man of sixty-five, died of a massive pulmonary embolus on the eleventh day after cup arthroplasty.

The remaining two deaths exhibit some unusual features:

Case 1—A woman aged thirty-three suffered from paraplegia from a pathological fracture of the body of the twelfth thoracic vertebra. The patient's general condition was good and before developing paraplegia she had had no complaints. The blood pressure, observed on a number of occasions, was 140/90 millimetres Hg. Laminectomy was proposed and anaesthesia was induced with 750 milligrams thiopentone and 10 milligrams d-tubocurarine chloride. A cuffed orotracheal tube was inserted and nitrous oxide, oxygen and cyclopropane administered. After the patient was placed in the prone position her blood pressure was 150/100 millimetres Hg. This was considered unusual

as in most subjects thiopentone produces a fall in blood pressure, but, in the absence of any alarming signs, 40 milligrams hexamethonium bromide were injected. After about two minutes, while skin preparation was proceeding, the patient's face became deeply congested as if due to spasm of the larynx or bronchi. While the airway was being checked congestion gave way to an ashen grey colour and neither pulse nor heart sounds could be elicited.

Post-mortem examination revealed a malignant phaeochromocytoma extending into the body of the twelfth thoracic vertebra, which had collapsed. Though the circulatory phenomena associated with benign phaeochromocytoma are not always present in the malignant variety, the pathologist stated that the findings in this case were consistent with the patient's having died in hypertensive crisis. Ganglionic blockade cannot prevent the hypertension which is related to the release of secretion from a phaeochromocytoma.

Case 2—This patient, a small, thin woman, sixty-three years of age, had pleural friction at the base of the left lung but no respiratory disability. Radiological examination revealed pleural thickening. She had been bedridden for over six months, but her general condition was fair and her blood pressure 135/90 millimetres Hg. With the patient in the lateral horizontal position femoral head replacement by an acrylic prosthesis was performed under general anaesthesia and hypotension induced with 40 milligrams hexamethonium bromide. The systolic pressure fell to 30 millimetres Hg. but had returned to 100/70 millimetres Hg. an hour after the end of the operation without resort to vasopressor drugs. Loss of blood was negligible and post-operative progress was satisfactory apart from a slight rise in temperature, coupled with an increase of the pleural friction at the base of the left lung for a few days.

One month later disarticulation at the right hip was carried out. Anaesthesia, as for the previous operation, was induced with 400 milligrams thiopentone and continued with nitrous oxide and oxygen with the addition of small quantities of cyclopropane. The patient was placed in a supine "jack-knife" position with a sandbag under the right hip and loin. The break in the table was approximately 15 degrees from the horizontal in its upper and 45 degrees in its lower half. The blood pressure was now 100/70 millimetres Hg. and 30 milligrams hexamethonium bromide were injected. Systolic pressure fell to about 40 millimetres Hg. and loss of blood was less than 20 millilitres. The right leg was elevated before ligation of the great vessels in order to return as much blood as possible to the general circulation. The operation was completed in seventy minutes.

The patient was moved from the operating table to her bed in the recovery room, placed in a 5 degrees Trendelenburg position and given oxygen. The systolic pressure was then 60 millimetres Hg. but twenty minutes later it had risen to 75 millimetres Hg. and the pulse rate was 88 per minute. She was awake and her colour and capillary circulation were good. Thirty minutes after the end of operation the systolic pressure fell to 65 millimetres Hg. A post-operative fall of blood pressure is always regarded as a grave sign and 5 milligrams methylamphetamine hydrochloride were injected. This produced no result and was repeated, again without effect. Blood transfusion was now started twenty minutes after the drop in blood pressure was first observed, 540 millilitres being given in fifteen minutes. In spite of these measures systolic pressure could not be raised. Since the loss of blood during operation had been negligible and no improvement was obtained by rapid transfusion, further intravenous therapy was thought to be contra-indicated. During the next twelve hours the pulse varied in rate between 68 and 80 per minute, was regular in time and force and easily palpable, and systolic pressure fluctuated between 40 and 60 millimetres Hg. The skin was dry and warm, the colour good and cerebration normal. Thereafter the pulse rate increased steadily and systolic pressure declined further in spite of repeated injections of methylamphetamine hydrochloride and continued administration of oxygen. At this stage a rapid intravenous infusion of Dextran was given but after about 150 millilitres it was found that the systolic pressure had fallen further and the infusion was therefore discontinued. Just before death, seventeen hours after operation, the pulse rate was 120 per minute and systolic pressure 20 millimetres Hg., the latter being taken by palpation without difficulty. The patient was conscious, her colour good and respiration normal until the end.

The post-mortem examination gave no evidence as to why this patient had failed to regain vasomotor control after an operation carried out under hypotension induced with hexamethonium bromide, though the use of a similar technique on her a month earlier had been uneventful. No deterioration in her circulation was observed during the period between the two operations and there was no evidence that her blood volume had been unduly disturbed during the last operation. Yet, this patient died in irreversible shock.

The one factor that differed materially in the two procedures was posture. There can be little doubt that the position adopted on the latter occasion must have impaired circulation, particularly as the patient's legs had been allowed to hang too steeply. The first thought which comes to mind is that the interference with venous return had produced a serious

reduction of cardiac output, but if this had been so one might have expected a circulatory emergency during operation. In fact, systolic pressure had fallen to a lower level during the first procedure.

There remain two further considerations: 1) The pronounced " jack-knife " position with elevation of the right loin, coupled with hypotension of a marked degree, is likely to have caused a reduction of blood flow through the liver. Though the theory first advanced by Shorr *et al.* (1945) that liver ischaemia leads to the release of vasodepressor material (VDM) and the production of irreversible shock has recently been discounted (Frank *et al.* 1952, Zweifach and Metz 1955), one feels that an inadequate hepatic circulation over a period of seventy minutes could cause serious metabolic abnormalities. 2) Tilt-table experiments by Deitrick *et al.* (1948) on normal healthy volunteers showed that continued immobilisation produces a marked deterioration of vasomotor efficiency and these changes were noted to begin within a week of enforced rest. The patient under discussion had been in bed for over seven months and it is thought that if prolonged immobilisation had been solely responsible for circulatory failure, the latter would have occurred as a result of the first operation.

It is suggested that the unfavourable posture adopted during the second procedure, combined with ganglionic blockade in a patient with an already impaired vasomotor efficiency, initiated irreversible shock.

DISCUSSION

The figures in Tables III and IV show that induced hypotension can effect a considerable saving of blood. Surgeons generally agree that operating conditions are improved and the duration of operation shortened. But it will be asked: " Are these advantages not obtained at an unjustifiable risk to the patient? " Experience in some 600 cases, including the group presented here, has shown that this technique can be safe provided certain safeguards are observed scrupulously. A reduction of arterial pressure will lower cardiac output, but as long as an adequate flow of fully oxygenated blood is maintained through the vital organs, this departure from the physiological norm has been shown to be within the limits of safety.

The following points must be carefully considered:

Posture—The patient must be positioned in a way which, while allowing drainage of blood from the site of operation, will not interfere with a constant and effective blood flow through such structures as brain, liver and kidneys despite the absence or depression of vasomotor control. Furthermore, unfavourable posture can by gravity or obstruction interfere with venous return and prevent adequate filling of the heart, thus leading to a further reduction of cardiac output. In this way, hypotension may be carried to a dangerous level. Thus, the acute " jack-knife " and reverse Trendelenburg positions are undesirable. The prone position can be dangerous, as shown by the observation that systolic pressures are, on the average, lower than in the supine. The face-down position tends to impede venous return. It has been said that hypotension can be intensified by employing a head-up tilt but this practice is not without the risks of reducing flow through the inferior vena cava and cardiac output and incurring the danger of cerebral ischaemia. Excessive slowing of pulse rate (below fifty per minute) indicates dangerous retarding of cardiac filling from a reduced venous return; it can be corrected by modifying posture.

Oxygenation—Obstruction of the airway must be scrupulously avoided and the respired mixture must contain a high percentage of oxygen. Hypovolaemia and anaemia must be corrected before operation, and if haemorrhage occurs once ganglionic blockade has been established, blood must be replaced promptly.

Degree of Hypotension—The frequent question: " What is the lowest reading of systolic blood pressure which can be regarded as safe? " cannot be answered by an arbitrary figure. The lowest safe level will vary in different individuals and according to posture. It would be a mistake to rely too rigidly on sphygmomanometer readings in assessing the patient's condition. An unchanged respiratory rate and rhythm and adequate capillary circulation and oxygenation

are the most reliable signs. The degree of ischaemia of the wound tissues is an important guide in as much as too marked a result must be regarded as a danger sign. This consideration becomes more serious the nearer the site of operation is to vital organs. In most cases modification of posture is sufficient to improve capillary flow, but if this is not effective the blood pressure must be raised to a safe level by a small dose of methylamphetamine hydrochloride.

Controlled respiration—Apart from the fact that normal spontaneous respiration is, in the presence of low systolic and pulse pressures, a valuable guide to the adequacy of the medullary blood flow, passive inflation of the lungs, particularly if forceful, reduces venous return. In this way, controlled respiration tends to lower cardiac output and further decrease arterial pressure.

Post-operative care—Vigilant supervision of the patient must continue after operation. Moving from operation table to bed should be carried out with the utmost care and there should never be more than one move. Intermediary transfer to a trolley has no place in the management of the hypotensive patient. The patient must remain under close supervision by the anaesthetist, in the recovery room attached to the theatre, until the blood pressure has reached at least 80 millimetres Hg. During this period a 5–10 degrees Trendelenburg position should be adopted, oxygen administered and respiratory obstruction guarded against. It has been the practice to allow the patient to return to the ward only after his systolic pressure had remained at a minimum of 80 millimetres Hg. for at least half an hour. If the pressure remains low in spite of blood loss during operation having been negligible or replaced, methylamphetamine hydrochloride will have to be administered. An initial dose of 3–5 milligrams is recommended because too rapid a rise of blood pressure is apt to provoke haemorrhage. Failure to produce or maintain a rise of pressure after a total dose of 10 milligrams should be taken as indicating a deficiency of blood volume and must be treated by transfusion. A fall of arterial pressure was observed in a number of patients as they were regaining consciousness, but it was found possible to correct this by an intravenous injection of morphine.

The following observations may be of interest:

Renal function—Post-operative oliguria or anuria were not encountered. This may appear contrary to the accepted view that 70 millimetres Hg. is the critical renal filtration pressure, which is based on observations in haemorrhagic hypotension with consequent vasoconstriction and ischaemia of the kidney. When systolic pressures below 70 millimetres Hg. are induced by means of ganglionic or sympathetic blockade, an adequate renal blood flow is possible.

Contra-indications—The conditions which were from the outset regarded as absolute contra-indications to inducing hypotension were coronary thrombosis and serious respiratory disability. Only one patient with a history of coronary thrombosis was given hexamethonium bromide—a woman of sixty-five years of age. She had a severe attack on the nineteenth day after operation but made a satisfactory recovery. Observation in this series has shown that periodic mental confusion is likely to be aggravated after induced hypotension, and patients with that history should be excluded. A considerable proportion of the patients under review suffered from arteriosclerosis of varying degree, and there was no indication that this condition should be regarded as a bar to the use of ganglionic blockade. Hypovolaemia and anaemia are definite contra-indications, unless they can be corrected before operation.

SUMMARY

1. Figures relating to blood loss and post-anaesthetic progress during and after 407 orthopaedic operations performed with the aid of hexamethonium bromide are presented.
2. Two deaths from circulatory failure are examined in detail.
3. The criteria that must be observed to ensure safety are discussed.
4. Measures designed to avoid reactionary haemorrhage are enumerated.
5. Observations regarding contra-indications are presented.

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REFERENCES

BROMAGE, P. R. (1956): Hypotension and Vital Capacity. Anaesthesia, **11,** 139.

BURCH, R. R. (1955): The Effects of Intravenous Hexamethonium on Venous Pressure of Normotensive and Hypertensive Patients with and without Congestive Heart Failure. Circulation, **11,** 271.

DEITRICK, J. E., WHEDON, G. D., and SHORR, E. (1948): Effects of Immobilization upon Various Metabolic and Physiologic Functions of Normal Men. American Journal of Medicine, **4,** 3.

DOTT, N. M. (1955): Personal communication.

DOUTHWAITE, A. H., and THORNE, M. G. (1951): The Effects of Hexamethonium Bromide on the Stomach. British Medical Journal, **i,** 111.

ENDERBY, G. E. H. (1950): Controlled Circulation with Hypotensive Drugs and Posture to Reduce Bleeding in Surgery: Preliminary Results with Pentamethonium Iodide. Lancet, **i,** 1,145.

FRANK, H. A., JACOB, S., FRIEDMAN, E. W., RUTENBURG, A. M., GLOTZER, P., and FINE, J. (1952): Traumatic Shock. XXII. Irreversibility of Haemorrhagic Shock and VDM Hypothesis: Failure of Ferretin to affect Arterial Pressure and Survival Period of Hepatectomized-Nephrectomized Dogs. American Journal of Physiology, **168,** 150.

KAY, A. W., and SMITH, A. N. (1950): Effect of Hexamethonium Iodide on Gastric Secretion and Motility. British Medical Journal, **i,** 460.

KAY, A. W., and SMITH, A. N. (1951): The Effect of the Ganglion-Blocking Methonium Salts on Gastric Secretion and Motility. Gastroenterology, **18,** 503.

KELLEY, R. T., FRIES, E. D., and HIGGINS, T. F. (1953): The Effects of Hexamethonium on Certain Manifestations of Congestive Heart Failure. Circulation, **7,** 169.

KERN, E. R. (1952): Problems of Anaesthesia and Transfusion in Major Surgery on the Hip Joint. Current Researches in Anesthesia and Analgesia, **31,** 350.

SHORR, E., ZWEIFACH, B. W., and FURCHGOTT, R. F. (1945): On the Occurrence, Sites and Modes of Origin and Destruction of Principles Affecting the Compensatory Vascular Mechanisms in Experimental Shock. Science, **102,** 489.

STEVEN, R. J. M., and TOVELL, R. M. (1954): Hexamethonium Salts as an Aid to the Orthopedic Surgeon. Journal of the American Medical Association, **154,** 402.

ZWEIFACH, B. W., and METZ, D. B. (1955): Relation of Blood-borne Agents Acting on Mesenteric Vascular Bed to General Circulatory Reactions. Journal of Clinical Investigation, **34,** 653.

TUBERCULOMA OF STRIATED MUSCLE

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For reasons not yet fully explained haematogenous tuberculosis of skeletal muscle is very uncommon. Reports of such lesions appear to be particularly scanty in the medical literature of the English-speaking nations. The problem has, however, interested some individuals who have sought to throw light on its pathogenesis and on its clinical manifestations.

True primary tuberculosis of muscle is said not to exist (Milch 1934). Haematogenous tuberculosis of skeletal muscle in the sense that it is a haematogenous infection secondary to infection elsewhere in the body is a rarity, and muscle itself is considered to occupy an important position among the tissues resistant to tuberculosis. To-day it is agreed that haematogenous tuberculosis of the striated muscle does occur. Culotta (1929), in 2,224 necropsies on tuberculous patients, discovered only four instances.

CASE REPORT

A woman aged forty-four was admitted to hospital complaining of a swelling on the front of the right thigh.

She had first noticed the swelling about twelve months before, and it had gradually increased. There was never any pain or sign of acute inflammation. She did not remember any injury to the right thigh, nor had she received an injection into the thigh.

Several days before admission she had noticed a sensation of " pins and needles " in the fingers and arm on the left side, and on waking in the morning she was found to have a left-sided hemiplegia. There had been no cough, no loss of weight and no night sweats.

On examination an obvious oval swelling was seen on the front of the thigh with its centre at the junction of the middle and lowest thirds. It extended downwards to within six centimetres of the upper border of the patella. The swelling was approximately 11·5 centimetres long by 5 centimetres at its widest. It was firm and well defined, and the overlying skin was of normal temperature and appearance, and moved easily over it. With the muscles relaxed the swelling was mobile transversely but not longitudinally. This mobility disappeared when the muscle contracted. There were full movements of all the joints. There was no swelling or pain on movement of the knee, nor was there any evidence of muscle weakness or atrophy. A few " shotty " glands were palpable in the groin. There was no oedema of the leg and the veins were not dilated. All reflexes were present. The swelling clearly involved the rectus femoris muscle, and a provisional diagnosis of fibrosarcoma was made.

Investigations—Haemoglobin 93 per cent; erythrocyte sedimentation rate 9 millimetres in first hour; leucocytes 12,100. The urine was heavily loaded with albumen and the centrifuged deposit showed thirty red blood cells to a one-sixth inch field. The urine was sterile. The blood urea was 38 milligrams per cent. Radiographs of the chest, spine, pelvis, hip, knees and femora showed no abnormality. Intravenous pyelography showed no abnormality in outline of the renal pelvis.

Operation—The tumour was found to be an encapsulated mass lying in the substance of the rectus femoris. The muscle was defined and separated from the neighbouring muscles, and the tumour with the whole muscle belly was removed in one piece. There was no communication with the underlying bone or with the knee joint. The wound was closed without drainage. It seemed probable from the macroscopic nature of the swelling that it was tuberculous; so streptomycin was given after the operation.

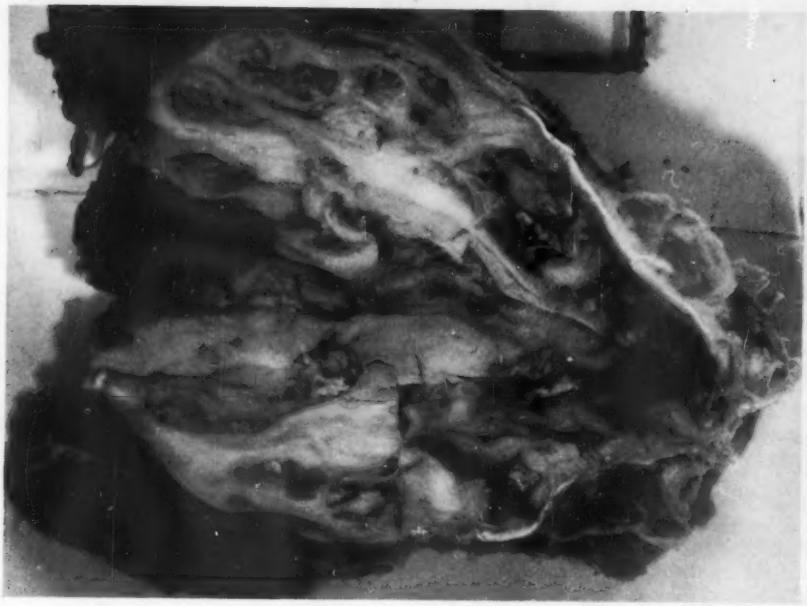

FIG. 1
Fresh specimen partly cut across and opened out showing tuberculous mass embedded in muscle.

FIG. 2
Separate halves of same specimen after fixing and mounting.

Pathological examination—The specimen consisted of muscle tissue and tendon, in which was embedded a tumour mass (Fig. 1). On sagittal section typical watery tuberculous pus was released, with flecks of caseous material. Examination of the cut surface of the mass

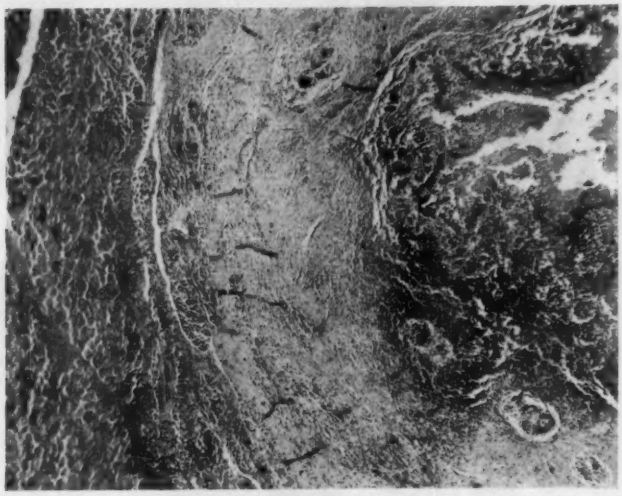

FIG. 3
Photomicrograph showing relationship between muscle fibres and caseating process. (×22.)

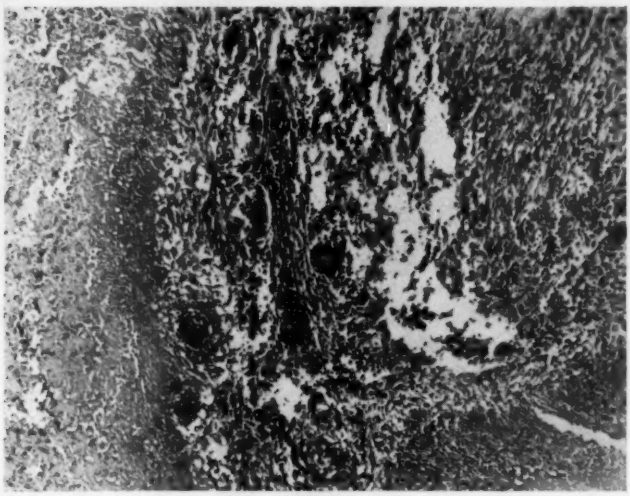

FIG. 4
Giant-cell and epithelioid-cell tubercles and necrosis. (×84.)

(Fig. 2) showed it to be well encapsulated, the edge being demarcated from the surrounding muscle by a well developed fibrous layer. The cut surface appeared to consist of a framework of thick fibrous trabeculae containing large abscesses lined with shaggy caseating granulation tissue.

Histological examination (Dr D. B. Richards)—The section showed several areas of caseating necrosis surrounded by a zone of epithelioid cells and giant cells with a peripheral zone of lymphocytes. Surrounding these areas a wide zone of collagenous fibrosis enclosed single atrophic muscle fibres. In this fibrous tissue were a few discrete tubercles composed of epithelioid cells and giant cells without any central caseation or peripheral lymphocytic aggregation. The microscopic picture was that of tuberculosis of muscle.

Examination of direct smear of pus—A few scanty acid-alcohol-fast bacilli were seen. Culture was sterile; guinea pigs were not inoculated. Professor J. W. S. Blacklock was able to demonstrate tubercle bacilli in the sections.

Comment—The hemiplegia, which improved considerably, was considered to be unrelated to the tuberculoma of muscle and was thought to be due to a cardiovascular accident secondary to prolonged nephritis.

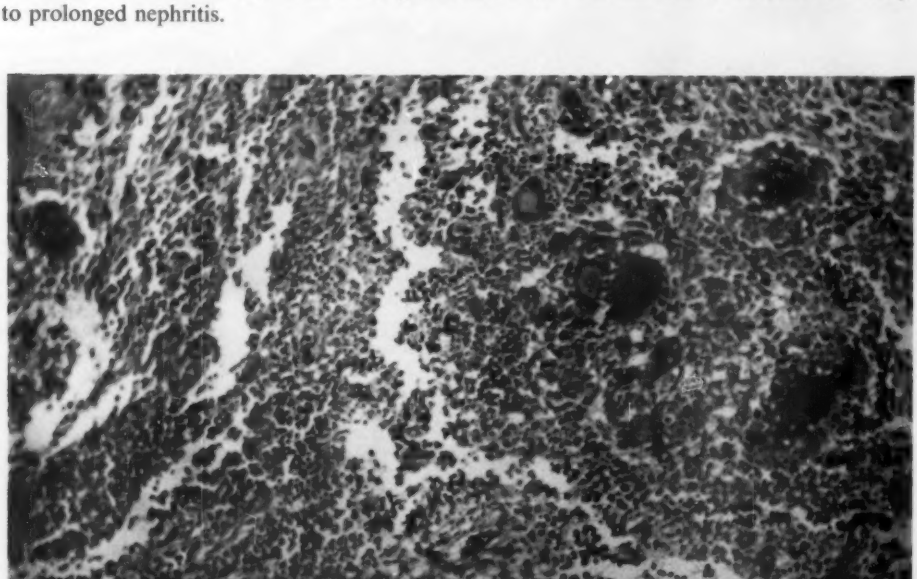

FIG. 5

High-power photomicrograph showing giant cells and epithelioid cells.

DISCUSSION

Formiggini (1911) in a review of fifty-nine cases accepted only twenty-seven as true examples of haematogenous tuberculosis of striated muscle. Hanke (1932) reviewed fifty-five authenticated cases of tuberculosis of muscle considered to be haematogenous. In 1948 Cortesi and Venturi accepted ninety-four published cases as authentic, and since then there appear to have been two further cases described, one by Gallarate (1950) and one by Magaldi (1952).

Tuberculosis can affect skeletal muscles in two distinct forms. There is the secondary and relatively common form, in which the tuberculous process spreads into the muscle by direct extension from neighbouring structures.

The other type, the so-called primary or haematogenous type, is much less common. It has been described by some authors as primary tuberculosis of muscle, but strictly speaking

it is haematogenous in origin because the lesion is considered to be carried to the muscle by the blood stream from a tuberculous focus elsewhere in the body. This focus may not be demonstrable. In the case reported here no other source of infection was found. These truly primary and latent centres almost always reside in the cervical, bronchial or mesenteric lymph nodes (Magaldi 1952).

There is, in addition, the rare possibility of a direct penetration of tubercle bacilli into the muscle tissue by hypodermic injections. Such a case was described by Coope (1946) after penicillin therapy. Magaldi (1952) quoted two similar cases after autopyotherapy and anti-typhoid injections.

The rarity of haematogenous tuberculosis of muscle has been the subject of much investigation. Several hypotheses have been suggested, none wholly satisfactory. It was suggested by Tria (1891), and again by Cagnetto (1925), that the production of lactic acid by the muscle tissue prevents infection, perhaps by a special bacteriolytic action (Tria). Zahnert (1929) ascribed resistance to the richness of the blood supply, and Culotta (1929) to the scantiness of the reticulo-endothelial system associated with the tendency of the bacillus to prefer connective tissue. Plummer, Sanes and Smith (1934) objected that this does not explain the frequent occurrence of tuberculosis in the liver and kidney, both as highly differentiated and well vascularised as muscle and having a similar dearth of lymphatic tissue. Pettinari (1936) also pointed out that this hypothesis explains only the slight tendency of the tissue to form giant cells and organise complete tubercles: it does not explain the resistance of the muscle fibres to the tubercle bacillus.

Richet (1927) observed that dogs in which he had reproduced tuberculosis of muscle responded favourably to the administration of fairly large doses of muscle juice and concluded that it contained a special muscle antitoxin with bacteriolytic potency. Hensel (1950) was unable to verify this in rabbits. Prussia (1931) explained Richet's good result by supposing that the nutritional element administered with the muscle juice enabled the animal to overcome the infection by its own natural resistance. Cagnetto (1925) noted that, in rabbits infected with trichinosis and subsequently infected with tuberculosis, the tuberculosis manifested itself predominantly in the muscles most affected by the trichinosis, possibly because this produced a local concentration of histiocytes.

Some authors have suggested that the contractile power of the muscle fibres is a defence against the infection of these fibres. It appears to have been established that cutting the nerve supply to the muscle increases the risk of haematogenous tuberculous infection of that muscle.

A review of these hypotheses suggests a biochemical explanation in which the products of muscle metabolism appear to play an important role in the resistance of muscle to tuberculous infection.

Saltykow (1902) injected tubercle bacilli into the femoral artery of animals. He showed that the first tuberculous lesions were in the intima and walls of the muscle vessels. The lesions then spread to the interstitial tissue. The muscle fibres themselves were involved only in a very late stage, and then only secondarily.

Pettinari (1936) also described the histological characteristics of the disease in muscle. He explained that the disease attacks the connective tissue in the interstices of the muscle. The muscle fibres themselves are not directly attacked, but are affected indirectly by compression and by the action of toxins. They show granular, fatty or hyaline changes. Neither clinically nor experimentally was there ever a violent specific reaction to the tubercle bacilli in the muscle. An initial leucocytosis is rare, and the formation of tubercles usually not well marked. He suggested that this supports the claim that the reason for the refractory nature of striated muscle fibres to infection by the tubercle bacillus is its slight receptivity and not its great power of resistance.

Haematogenous involvement of striated muscles occurs almost equally in the upper and lower limbs. Muscles of the abdomen and trunk are involved much less frequently. The

significance of injury has been disputed. Magaldi (1952) cited a number of authors who support and those who oppose the localising action of trauma. The much greater frequency of tuberculosis in the muscle groups liable to injury suggests that repeated trauma may influence its localisation; but the matter is still controversial.

Histology—Morphologically, Prussia (1931) and other authors distinguish three types: nodular tuberculosis, inflammatory tuberculosis myositis, and sclerosing myositis.

Nodular tuberculosis—These lesions form as small tuberculous nodules of varying size in the interstitial connective tissue, sometimes separated clearly from the surrounding tissue by a fibrous layer. The centre of the lesion caseates and may form a cold abscess. This may spread progressively to involve more tissue. Such an abscess can involve subcutaneous tissue and eventually skin to form a collar-stud abscess. The fibrous barrier may localise the abscess, the outside fibrous tissue gradually merging into the surrounding tissue.

Inflammatory tuberculous myositis or the granular-fungoid type—This type is characterised by the production of luxuriant granulation tissue which invades the interfascicular connective tissue. Giant cells and classical tubercle formation may be absent. The lesion can undergo liquefaction, thus forming a cold abscess.

Sclerosing myositis or tubercular cirrhosis—This is considered a rarer form, the inflammation causing a diffuse sclerosis with disappearance of muscle fibre. Inflammatory nodes with typical tubercle formation can be found in the sclerotic tissue or may be completely absent. The lesion itself assumes a cirrhotic appearance.

These types are of theoretical interest only as they may co-exist in the same lesion and represent different stages in the same process advancing to necrosis and caseation, depending on the virulence of the germ and the power of resistance of the patient.

Sex and age incidence—Culotta (1929) found that the incidence was unaffected by sex.

Magaldi (1952) found it generally an affection of youth, the third being the most affected decade.

Clinical features—The disease manifests itself insidiously. The swelling becomes slowly and progressively larger. Pain is usually inconspicuous and the functional limitation is usually slight. Constitutional disturbances are usually absent: when they do occur they include a slight fever, loss of weight, malaise and sweating. The general condition of these patients remains good unless there are tuberculous lesions affecting other viscera. The mass in the muscle substance is usually single. Normally movable, it becomes fixed on contracting the muscle. The consistency may be firm, soft or fluctuant, depending on the stage reached in the degeneration. The swelling is not usually attached to the skin or surrounding structures, and the regional lymph nodes are seldom involved. Examination of aspirated pus exceptionally reveals tubercle bacilli. There may be slight leucocytosis.

Diagnosis—The diagnosis clinically is usually difficult, especially the differentiation from the other and commoner tumours of muscle, such as benign and malignant lesions, the chronic granulomata and the cystic lesions of muscle. The condition is usually diagnosed at operation or after pathological investigation of the specimen. The haematogenous origin of the lesion must then be verified by careful investigation to exclude direct extension from a neighbouring tuberculous focus, thus excluding the commoner secondary type of tuberculous infection of muscle.

Course—It seems that the disease is chronic and progressive. Spontaneous healing has not been described. Dissemination may occur through the blood or lymph stream from the muscle focus. Extirpation of the focus, with general anti-tuberculous therapy, is therefore the treatment of choice. The functional result depends on the interference with muscle. The prognosis after satisfactory excision will depend on the general condition of the patient and the extent of any tuberculous lesion elsewhere in the body.

SUMMARY

1. An example of haematogenous tuberculous lesion of striated muscle is described.
2. Its rarity is stressed and pathological details described.
3. Some of the theories for the refractory reaction of muscle tissue to tuberculous infection are discussed, and experimental work is reviewed.
4. The prognosis, treatment, and the relationship of the disease to trauma are considered.

I am indebted to the Pathology Department of the Welsh School of Medicine for some of the microphotographs.

REFERENCES

CAGNETTO, G. (1925): Tuberculosi muscolare ematogena e trichinosi. Atti della Società medico-chirurgica di Padova, **3,** 22.

COOPE, P. J. (1946): Tuberculous Abscess Formation Following Penicillin Therapy. Proceedings of the Royal Society of Medicine (Section of Paediatrics), **40,** 161.

CORTESI, R., and VENTURI, G. (1948): Considerazioni anatomo-cliniche su due casi di tuberculosi primaria dei muscoli striati. Archivio Italiano di Chirurgia, **70,** 216.

CULOTTA, A. (1929): La tubercolosi muscolare. Rivista di Patologia e Clinica della Tubercolosi, **3,** 1.

FORMIGGINI, B. (1911): La tubercolosi primitiva dei muscoli triati. Clinica Chirurgica, **19,** 893.

GALLARATE, L. (1950): Contributo allo studio della tubercolosi muscolare; caso clinico. Minerva Chirurgica, **5,** 307.

HANKE, H. (1932): Zur Klinik der hämatogenen Muskeltuberkulose. Deutsche Zeitschrift für Chirurgie, **235,** 801.

HENSEL, G. (1950): Über traumatische Fascientuberkulose der Brustwand und ihre Behandlung. Tuberkulosearzt, **4,** 522.

MAGALDI, R. (1952): Stato attuale degli studi sulla tubercolosi ematogena, clinicamente primitiva, dei muscoli striati. Ospedale Maggiore, **40,** 550.

MILCH, H. (1934): So-called " Primary " Tuberculosis of Muscle. American Journal of the Medical Sciences, **N.S. 188,** 410.

PETTINARI, V. (1936): Tubercolosi muscolare primitiva. Rassegna Internazionale di Clinica e Terapia, **17,** 61.

PLUMMER, W. W., SANES, S., and SMITH, W. S. (1934): Hematogenous Tuberculosis of Skeletal Muscle. Report of a Case with Involvement of the Gastrocnemius Muscle. Journal of Bone and Joint Surgery, **16,** 631.

PRUSSIA, G. (1931): Su un caso di granuloma tubercolare a tipo pseudo-neoplastico delle pareti muscolari dell'addome. Policlinico (Sezione Pratica), **38,** 1,227.

RICHET, fils, C. (1927): La bactériolyse tissulaire du bacille de Koch. Journal de Physiologie et de Pathologie Générale, **25,** 666.

SALTYKOW, S. (1902): Ueber Tuberculose quergestreifter Muskeln. Centralblatt für allgemeine Pathologie und pathologische Anatomie, **13,** 715.

TRIA, G. (1891): Sul modo di comportarsi dell tessuto muscolare in alcune infezione. (Contributo allo studio delle influenze battericide esistenti nell'organismo sano.) Giornale Internazionale delle Scienze Mediche, **N.S. 13,** 361.

ZAHNERT, R. (1929): Über Muskel-und Sehnentuberkulose. Deutsche Zeitschrift für Chirurgie, **221,** 332.

ANKLE AND SUBTALAR FUSION BY A TRANSARTICULAR GRAFT

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The indications for pantalar fusion are: flail foot and ankle after poliomyelitis; severe talipes equinovarus; quiescent tuberculosis of the talus; severe fracture of the talus; and degenerative arthritis after these fractures. Pantalar and related arthrodeses have been performed in one or two stages.

One-stage methods. *Extirpation and replacement of the talus*—The first pantalar fusion was performed by Lorthioir in 1911. He excised the talus and after resection of all the cartilaginous surfaces he replaced it as a free graft (Fig. 1). This method was used with minor modifications by Albee (1915), Steindler (1923) and Crainz (1924).

In Guildal's (1926) technique the lower end of the fibula was divided obliquely at the level of the ankle and then hinged downwards, after which the cartilaginous surfaces were resected. Leikkonen (1950) mentioned that this technique was customary in Finland; the only modification was that at the end of the operation a metal spike was driven from below through the calcaneum and talus into the tibia. It was withdrawn ten days after the operation.

In the last ten years there have been three reviews of sizeable series of one-stage pantalar fusions. Leikkonen (1950) followed up twenty-eight pantalar fusions. He considered this number too small to allow general conclusions, although he preferred pantalar fusion to excision of the talus for stabilising a flail ankle. The results in six of his patients were poor. These six had some deformity and four had marked pain. In seventeen patients the results were good anatomically and functionally.

Patterson, Parrish and Hathaway (1950) performed twenty pantalar fusions, all for poliomyelitis. Seven were done in one stage with unfortunate early results, because sloughing of the wound occurred in three patients. There were also three pseudarthroses. These difficulties, however, were successfully overcome. The average follow-up of their cases was 4·7 years. Thirteen operations gave good results, five were fair and two were failures, but in this assessment they did not differentiate between the cases done in one stage and those done in two stages. They concluded that when there was a possibility of circulatory impairment the two-stage procedure was safer.

Hunt and Thompson (1954) reported thirty-eight pantalar fusions performed for poliomyelitis. The average period of immobilisation in children was 4·8 months and in adults 7·75 months. There were four pseudarthroses. Half their cases were considered to have an excellent result with but little limitation of their activities.

Methods using a bone graft—The ankle and subtalar joints and the ankle and talo-navicular joints have been successfully arthrodesed by bone grafts placed antero-laterally, anteriorly or posteriorly.

Watson-Jones (1944) performed a fusion of the ankle and subtalar joint for degenerative arthritis, consequent upon a fracture of the talus. Through an antero-lateral incision he removed all degenerated cartilage, inlaid a bone graft in a trough cut on the lateral surface of the tibia and talus and impacted it into a socket in the calcaneum (Fig. 2). The upper end of the graft tended to spring and was screwed down. The published radiographs suggest that some difficulty was experienced in aligning the talus. Union occurred in four months.

Ansart (1951) used an anterior bridge graft (Fig. 3). In this technique the joint surfaces were not denuded of their cartilage, but a tibial graft was placed in a slot extending from the lower end of the tibia across the talus to the navicular. This necessitated considerable equinus. Moreover, the graft fractured in some cases. Immobilisation in plaster was used for six months and in cases where the graft fractured for up to one year.

Staples (1956) reported four successful posterior arthrodeses of the ankle and subtalar joints. He rawed the posterior surface of the tibia and the talus and made a socket in the calcaneum. Into the bed thus fashioned he placed an iliac graft and screwed its upper end to the tibia (Fig. 4).

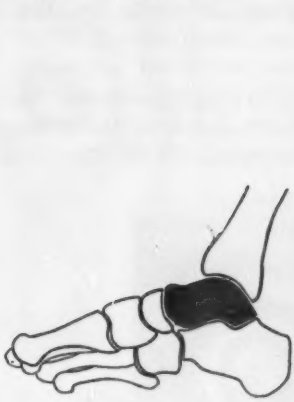

FIG. 1

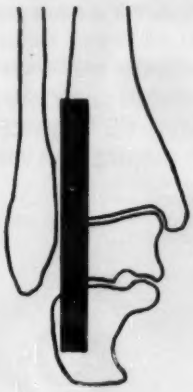

FIG. 2

FIG. 3

Figure 1—Lorthioir's method. The talus is replaced as an avascular graft. Figure 2—Watson-Jones's operation. A graft is inlaid into a lateral slot in the tibia and talus and driven into a socket in the calcaneum. Figure 3—Ansart's operation. The anterior bridge graft does not immobilise the subtalar joint.

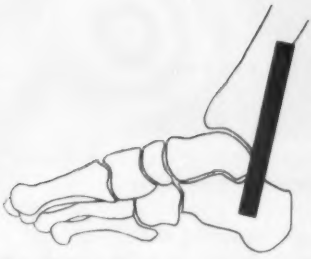

FIG. 4

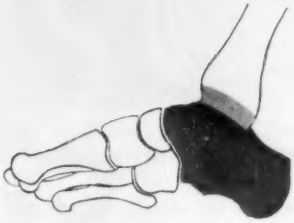

FIG. 5

FIG. 6

Figure 4—Staples's operation. A graft is applied to the osteotomised posterior surfaces of the tibia and talus and placed in a socket in the calcaneum. Figure 5—Pantalar fusion in two stages. Triple arthrodesis may either precede or follow ankle fusion. Figure 6—Method used by the author. The ankle and subtalar joints are transfixed by a graft.

Two-stage methods. *Triple arthrodesis followed by ankle fusion*—Liebolt (1939) recommended a tarsal arthrodesis by Hoke's technique followed by fusion of the ankle through an anterior approach (Fig. 5). Internal fixation was not used. Although he did not state how long it took for sound pantalar fusion to occur the least disability period must have been of the order of seven to eight months. His results based on a three-year follow-up of eighty-two patients were as follows: 13 per cent of the patients required secondary operations. Three per cent were failures, 17 per cent had only fair results mainly due to improper equinus, and good results were obtained in 80 per cent.

Ankle fusion followed by triple arthrodesis—Charnley (1953) advocated compression arthrodesis of the ankle followed after an interval of two months by tarsal fusion. Since by his method ankles are fused at the end of two months and a triple arthrodesis unites in three to four months, the minimum total disability period is again seven to eight months. He stated that he had performed five pantalar fusions but did not give detailed results.

METHOD AND MATERIAL

The method that I have used consists in the insertion of a graft from below through the calcaneum and talus into the tibia (Fig. 6). Six patients have been operated on, one of them on both sides. Three patients were suffering from quiescent tuberculosis and the other three

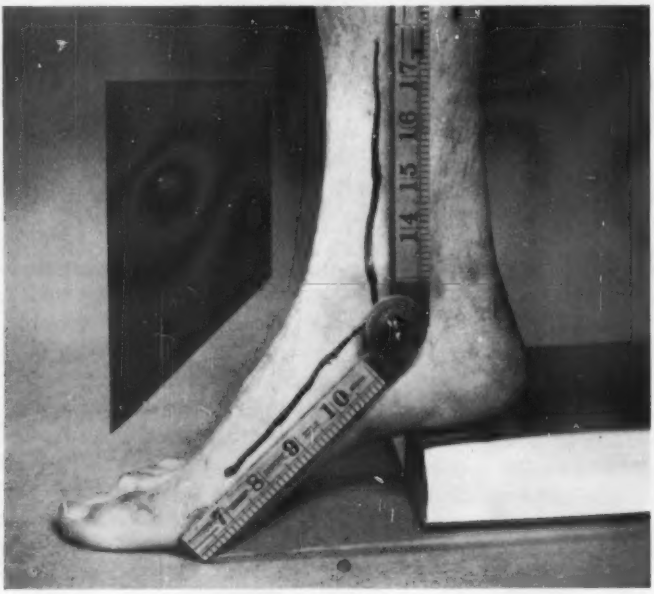

FIG. 7
Method of determining the degree of equinus before operation. Inset shows pattern.

had flail feet and ankles after poliomyelitis. The case histories are summarised in Table I. Complete pantalar arthrodesis was carried out three times, arthrodesis of only the ankle and subtalar joint once, and fusion of only the ankle joint three times.

TECHNIQUE OF OPERATION

Determination of degree of equinus—Before operation blocks are placed under the patient's heel to give the desired degree of equinus and the leg-foot angle is measured (Fig. 7). A pattern corresponding to this angle is then cut from a piece of corrugated rubber for use during the operation. If there is a fixed deformity the angle and pattern are obtained from the normal side.
Pantalar arthrodesis—Through a lateral " hockey-stick " incision the lowest six inches of fibula are resected, and the articular cartilage is removed from the ankle and subtalar joints, which can be done without dividing the medial and superior soft-tissue attachments of the talus. Next, through an axial plantar incision an inch of the inferior calcaneal surface is bared. A guide wire is driven up to pierce the centre of the talus and pass three or four inches

up the centre of the medullary cavity of the tibia. Its progress across the subtalar and ankle joints is visible. The leg-foot angle is checked against the pattern and with the heel in the neutral position or in slight valgus a tunnel is cut round the guide wire with a cannulated drill. Meanwhile an assistant has removed the cartilage from the lower end of the fibular graft and pointed and trimmed its lower end. This graft, which should fit the hole like a slightly oversize square peg, is now gently tapped up until its lower end is flush with the calcaneum. One or two extra taps ensure close coaptation of the four surfaces to be fused. The talo-navicular joint surface is next resected, if necessary through a separate incision. The navicular is secured to the talus by means of either an inlay graft (Fig. 8) or a slender beef bone peg (Fig. 9).

FIG. 8

Case 2—Pantalar arthrodesis in two stages. Radiograph taken fifteen months after first and six months after second operation. Note the graft across the resected talo-navicular joint.

The limb is protected by an above-knee plaster for four months, but weight bearing is permitted after three months. Some patients require a rocking sole afterwards.

Modifications. Incomplete pantalar fusion—Talo-navicular fusion may be omitted in operations done for poliomyelitis if after insertion of the fibular graft the foot is stable. This was done in Case 5 (Fig. 10).

Insertion of the graft without opening the ankle—This procedure was carried out twice. In Case 1 tuberculous disease had obliterated the subtalar joint eight years before (Fig. 11) and unhealthy skin round a recently healed antero-lateral sinus prevented an anterior or a lateral approach. A fibular graft was taken from the sound leg. Sound fusion of the ankle was obtained (Fig. 12).

In Case 4 the left ankle had not fused nine months after a two-stage operation as recommended by Liebolt (1939). A Merthiolate preserved graft was used in this case.

Fusion of the ankle and lengthening of the calcaneal tendon—In Case 6 the ankle was in extreme equinus after a previous triple arthrodesis. Through a lateral approach the calcaneal tendon was lengthened; the ankle was denuded of cartilage and transfixed with the resected fibula.

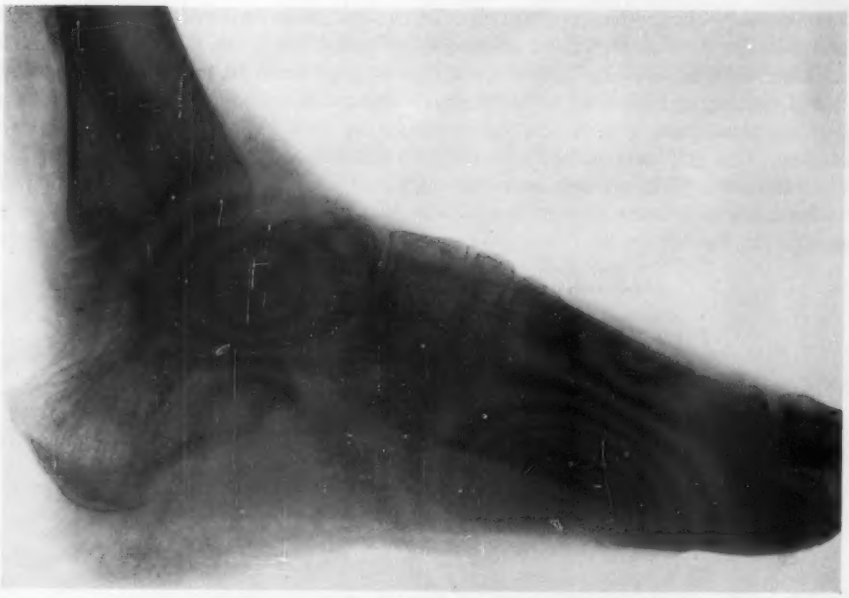

FIG. 9
Case 3—Pantalar arthrodesis. Radiograph of left ankle five months after operation. Note the slender beef bone peg fixing the talus to navicular.

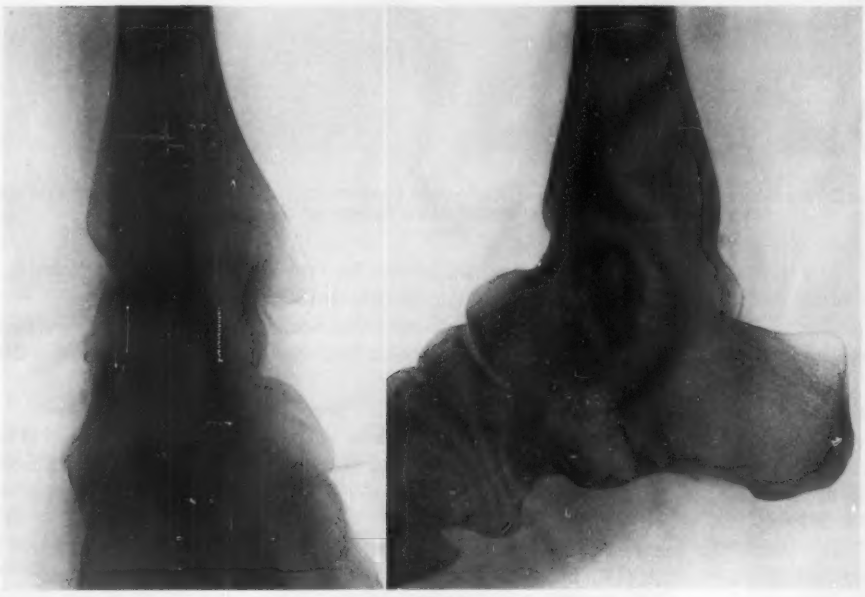

FIG. 10
Case 5—Radiograph of right ankle nine months after fusion of the ankle and subtalar joints.

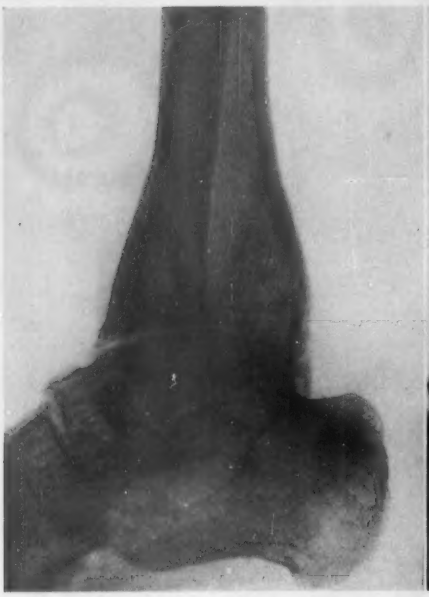

FIG. 11

FIG. 12

Case 1. Figure 11—Radiograph of right ankle before arthrodesis. Note the obliteration of the subtalar joint. Figure 12—Radiograph taken seventeen months after arthrodesis of ankle by transfixion graft without exposing the joint surfaces.

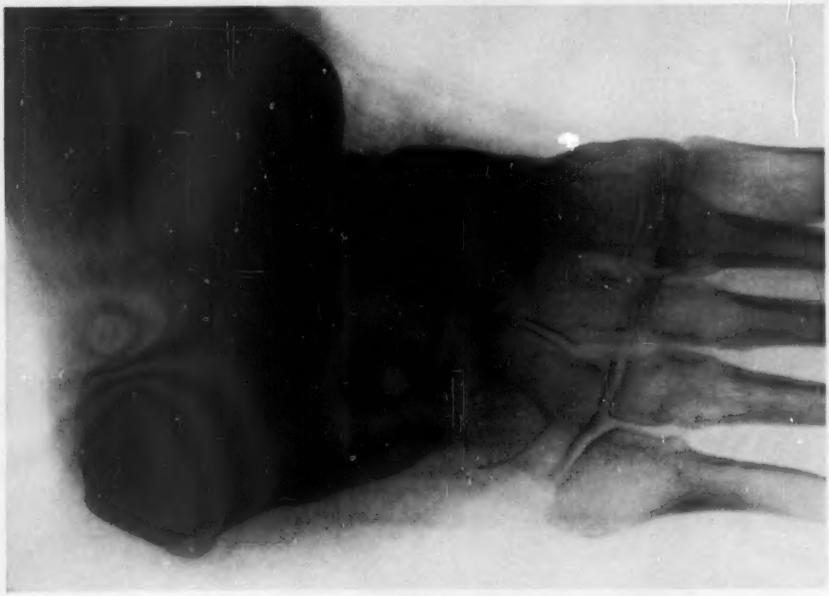

FIG. 13

Case 7—Radiograph of right ankle showing solid pantalar fusion. Note the prominent calcaneal tubercles.

RESULTS

None of the cases was complicated by sepsis. The shortest period of immobilisation was three months (Case 6), and the longest seven and a half months (Case 5) but this ankle was probably immobilised for two months too long. The average period of immobilisation for all the cases was 4·9 months. For the three one-stage pantalar fusions it was five months.

TABLE I

SUMMARY OF CASE HISTORIES

Case	Sex	Age (*years*)	Side	Diagnosis	Pre-operative condition	Procedure	Length of immobilisation in above-knee plaster	Result	Follow-up (*months*)
1	M	28	R	Tuberculosis of ankle. Recrudescence of disease	Sinus at ankle healed two months. Subtalar fusion from first attack aged twenty	Insertion of left fibular graft across ankle from below	4½ months	Solid, painless fusion	17
2	F	62	R	Tuberculosis of talus	Quiescent	Pantalar arthrodesis	Two periods of three months each	Solid at three months. Wrecked talo-navicular fusion in fall. One secondary operation. Final result—solid, painless fusion	25
3	M	17	L	Tuberculosis of talus. Osteoarthritic subtalar and talo-navicular joints	Quiescent	Pantalar arthrodesis	5 months	Solid, painless fusion	12
4	F	17	L	Poliomyelitis	Slow union at ankle after two-stage pantalar arthrodesis	Insertion of banked graft across ankle from below	4 months	Solid, painless fusion	13
5	F	17	R	Poliomyelitis	Completely flail foot and ankle	Arthrodesis of ankle and subtalar joints only	7½ months	Solid, painless fusion	10
6	M	32		Poliomyelitis	Ankle in extreme equinus. Triple arthrodesis nine years before	Arthrodesis of ankle and lengthening of calcaneal tendon	3 months	Solid, painless fusion	14
7	F	24	R	Poliomyelitis	Completely flail foot and ankle	Pantalar arthrodesis	4 months	Solid fusion. Calcaneal tubercles painful and tender	19

In Cases 1 and 6, in which the subtalar joints were already obliterated and only the ankles were arthrodesed, sound union occurred in four and a half months and three months.

Only one patient (Case 2) required a secondary operation after having wrecked her talo-navicular arthrodesis in a fall. All the patients could walk well and wear stock shoes. Pain in the heel was encountered once in a patient who had unduly large calcaneal tubercles (Fig. 13). Her plantar scar was neither painful nor tender. She required a sorbo heel cushion and a caliper.

DISCUSSION

The principle of this operation is not new. As long ago as 1906 Lexer (quoted by Leikkonen 1950) drilled a small hole through the calcaneum and talus into the tibia and drove up a bone graft which had been taken from a corpse and boiled for twenty-four hours. Later he used autogenous tibial and fibular grafts. But this method does not seem to have been very successful (Leikkonen 1950). Subsequently transarticular grafts were used successfully. Thus Hatt (1940) and Brittain (1942) independently described a method of fusing the ankle in which a central transarticular graft was driven down the tibia into the talus. Armstrong (1945) also used a transarticular graft in the treatment of severe calcaneal fractures by subtalar fusion. After removal of the articular cartilage he passed a graft downwards and backwards through the neck of the talus into the posterior third of the calcaneum.

Metallic internal fixation has also been employed in this region. Adams (1948) drove a trifin nail from the lower surface of the calcaneum into the tibia to provide rigid immobilisation for an ankle arthrodesis with slow union. Küntscher (1953) recommended that for simultaneous ankylosis of ankle and knee a long nail be driven into the femur starting from the sole of the foot across the subtalar, ankle and knee joints.

From my review of the literature it appears that the cases described here are the first recorded examples of the use of a transarticular graft to fuse both the ankle and subtalar joints.

Although only seven such fusions have been performed their study nevertheless suggests that the use of the transarticular graft provides advantages over other methods: 1) It is a one-stage procedure relieving the patient of the anxiety of having to undergo two operations; 2) union occurs in adults in as little as four to five months; 3) pseudarthroses are unlikely because every joint to be arthrodesed is securely immobilised by internal fixation; 4) the desired degree of valgus, varus, equinus or calcaneus is easily determined at the time of the operation and this position is firmly held by the graft and not lost when the plaster is changed; 5) the operation is suitable for cases of quiescent tuberculosis of the talus because the talus is not rendered ischaemic.

If the subtalar joint is already obliterated and ankylosis of the ankle joint only is necessary the following advantages may be added: 6) because of the lateral approach the heel cord can be lengthened without making a second incision; and 7) in cases of tuberculosis it seems that the mere insertion of the graft can lead to bony fusion without opening the ankle.

SUMMARY

1. Three pantalar, one ankle and subtalar, and three ankle arthrodeses have been performed by a technique, the essential step of which is the insertion of a transarticular graft from below. Union has occurred in four to five months.

2. A method is described of determining the degree of equinus before the operation and securing it during the operation.

3. Pantalar fusion by this technique compares favourably with the methods described so far.

I should like to thank Mr H. Jackson Burrows and Dr Glyn Jones for the help they have given me; and Mr E. Andrews for the photographs.

REFERENCES

ADAMS, J. C. (1948): Arthrodesis of the Ankle Joint. Journal of Bone and Joint Surgery, **30–B**, 506.

ALBEE, F. H. (1915): Bone-graft Surgery, p. 335. Philadelphia and London: W. B. Saunders Company.

ANSART, M. B. (1951): Pan-arthrodesis for Paralytic Flail Foot. Journal of Bone and Joint Surgery, **33–B**, 503.

ARMSTRONG, J. R. (1945): Bone-grafting in the Treatment of Fractures, p. 156. Edinburgh: E. & S. Livingstone Ltd.

BRITTAIN, H. A. (1942): Architectural Principles in Arthrodesis, p. 58. Edinburgh: E. & S. Livingstone.

CHARNLEY, J. (1953): Compression Arthrodesis, p. 150. Edinburgh and London: E. & S. Livingstone Ltd.
CRAINZ, S. (1924): L'artrodesi del piede per mezzo dell'astragalectomia seguita da reimpianto parziale o totale dell'astragalo. Policlinico (Sezione Chirurgica), **31**, 1.
GUILDAL, P. (1926): Une modification de technique de l'arthrodèse du pied. Revue d'Orthopédie, **3**, sér. **13**, 143.
HATT, R. N. (1940): The Central Bone Graft in Joint Arthrodesis. Journal of Bone and Joint Surgery, **22**, 393.
HUNT, W. S., Jun., and THOMPSON, H. A. (1954): Pantalar Arthrodesis. Journal of Bone and Joint Surgery, **36–A**, 349.
KÜNTSCHER, G. (1953): Die Technik der " geschlossenen " Hüftarthrodese. Chirurg, **24**, 404.
LEIKKONEN, O. (1950): Astragalectomy as an Ankle-stabilizing Operation in Infantile Paralysis Sequelae. Acta Chirurgica Scandinavica, **100**, 668.
LIEBOLT, F. L. (1939): Pantalar Arthrodesis in Poliomyelitis. Surgery, **6**, 31.
LORTHIOIR, J. (1911): Huit cas d'arthrodèse du pied avec extirpation temporaire de l'astragale. Journal de Chirurgie et Annales de la Société Belge de Chirurgie, **11**, 184.
PATTERSON, R. L., Jun., PARRISH, F. F., and HATHAWAY, E. N. (1950): Stabilizing Operations on the Foot. Journal of Bone and Joint Surgery, **32–A**, 1.
STAPLES, O. S. (1956): Posterior Arthrodesis of the Ankle and Subtalar Joints. Journal of Bone and Joint Surgery, **38–A**, 50.
STEINDLER, A. (1923): The Treatment of the Flail Ankle; Pan-astragaloid Arthrodesis. Journal of Bone and Joint Surgery, **5**, 284.
WATSON-JONES, R. (1944): Fractures and Joint Injuries. Third edition. Vol. **2**, p. 840. Edinburgh: E. & S. Livingstone Ltd.

EXTRASKELETAL OSTEOCHONDROMATA

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Bone-forming tumours in extraskeletal tissues are rare. Stout (1953) found only eighty-five such growths among 7,337 benign mesenchymal tumours of " soft " tissues in the records of the Laboratory of Surgical Pathology of Columbia University during forty-five years. Osteomata have been described in the breast (Cooper 1829, Robinson and Spencer 1950, Ling and Stewart 1955), in retroperitoneal tissues (Kretschmer 1938, Wilson 1941) and even in the tongue (Witchell 1949). A patient of Robillard's (1941) had an ossification of the infrapatellar pad of fat, like the intracapsular, extrasynovial masses of bone and cartilage that Kautz (1945) considered to be osteomata. Kautz attributed the original description of such tumours to Kienbock, who is quoted as having found them in other joints than the knee. Geschickter and Copeland (1949) mentioned three osteochondromata of bursal origin, and twenty-two arising in tendons just above their osseous insertion.

From this review it appears that extraskeletal osteomata and osteochondromata can occur at many sites. The following two examples appear to be the first to be described in the foot.

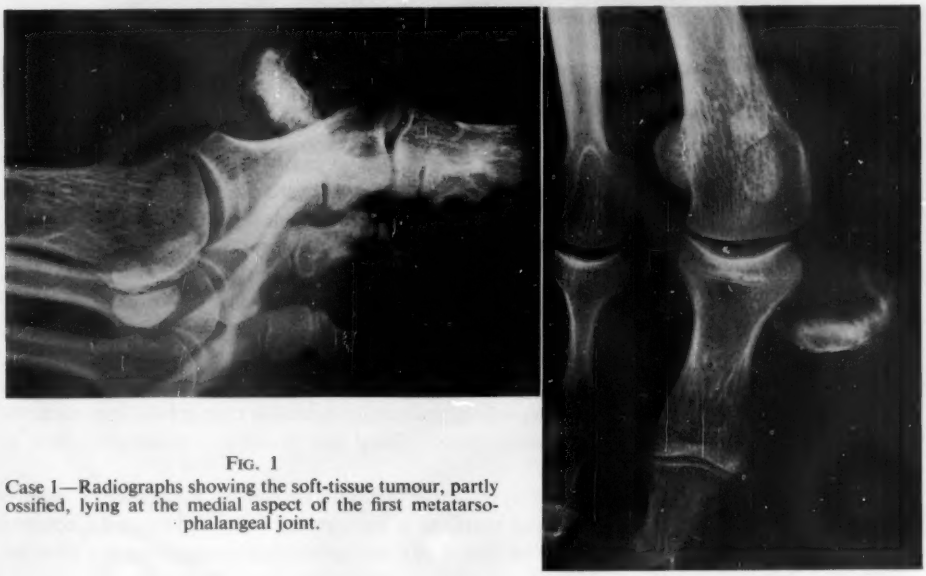

FIG. 1

Case 1—Radiographs showing the soft-tissue tumour, partly ossified, lying at the medial aspect of the first metatarso-phalangeal joint.

CASE REPORTS

Case 1 (Patient of Mr R. Broomhead)—A woman aged thirty-nine years attended hospital with a painless swelling of her foot. The swelling had been present for nine months and was gradually enlarging. It was a firm mass, one inch across, at the medial aspect of the first metatarso-phalangeal joint. It could be moved over the deeper structures. Radiographs (Fig. 1) showed a round soft-tissue swelling which was partly ossified.

The tumour was excised. It was lobulated, and its deep surface formed one wall of a bursa between it and the joint capsule. Histologically the tumour was a simple osteochondroma.

Case 2 (Patient of Mr D. Ll. Griffiths)—A man aged fifty-three years complained of pain under the forefoot. The pain was relieved by wearing a sandal, but was accentuated by treading on anything hard. A callosity was present under the head of the fourth metatarsal. Radiographs showed a bony opacity in the soft tissues (Fig. 2). Through a curved incision

FIG. 2
Case 2—Radiographs showing the area of ossification superficial to the head of the fourth metatarsal.

skirting the callosity the bony tumour was removed. It lay in the subcutaneous tissue, and between it and the underlying tendons was a small bursal cavity. Structurally, the tumour consisted mainly of cancellous trabeculae, in many of which were islands of cartilage. There was a complete capsule of fibrous tissue, but at one aspect, that towards the bursa, there was a transition from fibrous tissue to fibrocartilage, to the cartilage which adjoined the bony trabeculae.

DISCUSSION

The large proportion of cartilage present in the first of these tumours justifies its classification as an osteochondroma. In the second case there was a preponderance of bone. Such tumours have been described by previous authors as osteomata. Nevertheless the presence of cartilage in many of the cancellous trabeculae indicates that growth has occurred by ossification of a cartilaginous primordium. They are, therefore, better described as osteochondromata.

These cases are not examples of heterotopic ossification, for in that process bone is formed directly from fibrous tissue, and cartilage is not present (Geschickter and Copeland 1949). Furthermore, the clinical state and history of these patients never suggested any previous necrosis, scarring or calcification, the usual basis of heterotopic bone formation.

I thank Mr D. Ll. Griffiths and Mr R. Broomhead for their permission to publish the cases which form the basis of this paper.

REFERENCES

COOPER, Sir A. (1829): Illustrations of the Diseases of the Breast, p. 64. London: Longman, Rees, Orme, Brown & Green.

GESCHICKTER, C. F., and COPELAND, M. M. (1949): Tumors of Bone. Third edition. Philadelphia, London, Montreal: J. B. Lippincott Company.

KAUTZ, F. G. (1945): Capsular Osteoma of the Knee Joint. Report of Four Cases. Radiology, **45**, 162.
KRETSCHMER, H. L. (1938): Retroperitoneal Pararenal Osteoma. Surgery, Gynecology and Obstetrics, **67**, 108.
LING, W. H. G. M., and STEWART, I. S. (1955): A Bony Tumour of the Breast. British Medical Journal, **ii**, 364.
ROBILLARD, G. L. (1941): Ossification of Infrapatellar Bursae and Fat Pad. American Journal of Surgery, **N.S. 51**, 442.
ROBINSON, R. H. O. B., and SPENCER, H. (1950): A Cancellous Osteoma in the Breast. British Journal of Surgery, **37**, 481.
STOUT, A. P. (1953): Tumors of the Soft Tissues. Atlas of Tumor Pathology, Section ii, Fascicle 5. Washington: Armed Forces Institute of Pathology.
WILSON, H. (1941): Extraskeletal Ossifying Tumors. Annals of Surgery, **113**, 95.
WITCHELL, I. S. (1949): Osteoma of the Tongue. Archives of Otolaryngology, **50**, 453.

CALCIFICATION OF ARTICULAR CARTILAGE

Report of a Case

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A few cases have been described of patients with recurrent multiple arthritis, which has been variously diagnosed as gout or rheumatoid arthritis, and which has been found to have a curious calcification apparently affecting the articular cartilage. Edwards and Davis (1953) described a man of forty-five who had a history of three years of intermittent pain in the knees, right ankle and right shoulder, and who attended with a swollen, painful right knee which had troubled him for two weeks. The joint was warm and had an effusion into it but it retained a full range of movement. No other joint was affected at the time. The knee became normal again in four weeks simply with rest in bed. Four months later there was another slight attack. Radiographs showed changes like those we are to describe in our case, and which were found in the knees, shoulders, the left carpus and the spine between the bodies of C.6–7 and T.10–11. Radiological appearances were unchanged five months later. Edwards and Davis considered that the unusual feature of their case was calcification of hyaline articular cartilage. They pointed out that many joints so affected had been symptomless and thought that the presenting symptoms may have been due to early osteoarthritis. There was no evidence of a generalised disturbance of calcium metabolism.

Harmon (1944) described two cases. The first was suggestive of degenerative arthritis in a man of seventy-five who had had " rheumatism all over " for thirty years but especially intermittent pain and swelling of the left knee. Radiologically there was calcification following the contours of the articular cortex of both femoral condyles in each knee. The knees also showed osteoarthritis. The patient was treated with rest, extension of the legs and aspiration of the knees, with relief. Later the patient died with an enlarged prostate, urinary infection and auricular fibrillation. At necropsy sections of the semilunar cartilages showed only " extremely light and sporadic " yellowish discoloration indicating small scattered foci of calcification. These did not cast shadows when the semilunar cartilages were radiographed. Articular cartilage was missing from the central portions of the medial tibial and femoral condyles, these defects being due, it was thought, to advanced degenerative changes. Sections of the cartilage peripheral to the bare bone showed, grossly and microscopically, an advanced state of diffuse calcification.

The second case was of a man of fifty-five thought to have gout. The history was of four days of pain in the right knee with an effusion into the joint, followed by a similar affection of the left knee. The patient's temperature ranged between 100 and 102 degrees Fahrenheit. The total white cell count was 9,800 per cubic millimetre and erythrocyte sedimentation rate was 21 millimetres in the first hour (Cutler-tube method). The serum calcium was 10·4 milligrams per cent, the serum phosphorus 2·5 milligrams per cent, the urea nitrogen 19 milligrams per cent, and the serum uric acid on three separate occasions 6·7 milligrams, 7·6 milligrams, and 10 milligrams per cent respectively. Radiologically there was no evidence of gout, but the knees and wrists showed calcification following the contours of the articular surfaces of the joints. Radiographs two years later showed a slight increase of the calcification. The patient was treated with rest in bed, colchicine, bandages to the knees, and traction on the right leg. A slightly cloudy yellow liquid was aspirated from the right knee and contained a moderate number of polymorphonuclear neutrophil cells and was sterile. It was pointed out that no specific treatment was given to the two patients, except of the acute symptoms.

Harmon claimed that there was no account in the literature of this kind of dense calcification in articular cartilage.

Wolke (1935) examined radiographs of 2,569 knees and found calcification of the semilunar cartilages in eight cases; and five of these eight had other joints affected, including calcification of some intervertebral discs and the articular cartilages of various joints. This was remarked as something that had not been observed before. So far as could be judged there had been no symptoms. In four cases the changes were known to have been unaltered in from one to nine years.

Israelski (1931) reported a case of diffuse calcification of the semilunar cartilages in both knees, there being smaller patches of calcification outside the semilunar cartilages and a narrow band of calcification lying parallel to the articular surfaces of the femurs. The large arteries around the joints were calcified. The patient was a man of sixty, with a history of diabetes mellitus for three years. He complained of pains and stiffness in the knees, examination of which revealed only coarse crepitation on movement. He had no treatment and no change was observed in the joints during the year.

CASE REPORT

The present account is of a coloured Jamaican woman of about thirty-one years of age. There was no family history of arthritis. Married for twelve years, she had had an abortion at three months, two years after marriage, and denied further pregnancies. She denied having had venereal disease, and said that her general health had been good. She said that she had nausea before her menstrual periods and before attacks of joint pains (which were unrelated to menstruation). Four years before our seeing her she had weighed 150 lb. and had lost some 30 lb. since.

The history of her arthropathy is compiled from notes taken at the Kingston Public Hospital, which she first attended in 1952, and from her own account to us at the University College Hospital, Jamaica, which she first attended in 1954. The presenting symptom was always of joint pain and she was first troubled in 1945 when she was between twenty-four and twenty-seven years (there are discrepancies in her declared age at various times). Between 1945 and 1952 she had four similar attacks of joint pain and the first three were treated with injections given by her own doctor and each attack had gone entirely within a few weeks. The fourth attack occasioned her first admission to hospital in January 1952. At that time she had been unwell for two weeks, having had a sudden onset of fever and " tonsillitis " followed, a few days later, by joint pain and loss of appetite. On examination she had a temperature of 101 degrees Fahrenheit, a pulse of 116 per minute, and a respiration rate of 24 per minute. There was a trace of protein in the urine. The right tonsil was inflamed and the liver and spleen were enlarged and tender. The knees were swollen and inflamed, the tibiae tender, and the ankles and feet were swollen. The next day the right wrist was swollen and tender. The temperature was of the order of 101 degrees Fahrenheit, then 99 degrees Fahrenheit for two days and thereafter she was afebrile until her discharge from hospital three weeks later. A diagnosis of rheumatoid arthritis was made and she received intramuscular injections of Myocrisin, four in all, beginning with 0·01 gramme and rising by 0·01 gramme with each dose. She had also had an injection of procaine penicillin, 600,000 units, and sodium bicarbonate, sodium salicylate and ferrous sulphate by mouth. Two weeks after her discharge she was readmitted to hospital with a history of fever but with no sore throat. The pains in her joints had returned, moving from the left ankle to the left hip, the right ankle, right wrist, right shoulder, elbow, knee, and a sacral joint. She was given a similar course of Myocrisin and discharged three weeks later.

She was next seen by her own doctor two years later, when she had an acute attack of joint pain and fever which he treated with an injection of one million units of penicillin and with salicylates by mouth. She was improved by the time she was admitted to the Kingston

Public Hospital again three days later, and gave a history of three weeks of fever and fleeting pains in various joints. At the onset the pain had been in the left heel. There had been swelling and tenderness of the joints which had subsided, leaving the joints " stiff." Examination showed that she had a temperature of 100·6 degrees Fahrenheit (which subsided over the next three days), swelling and tenderness of the right ankle, but merely stiffness of the right wrist and knee. For the first time, apparently, the patient had had pain in a small joint and for two days before admission had pain in the metacarpo-phalangeal joint of the right index finger. There was no deformity of the hands. She was discharged after twelve days' treatment

TABLE I
BLOOD CELL EXAMINATIONS

Date	Haemoglobin (*grammes per cent*)	Red blood cells (*million*)	Packed cell volume (*per cent*)	White blood cells	Erythrocyte sedimentation rate
30.1.52	9·6	3·7	—	14,300	—
6.3.52	11·3	3·85	—	8,200	—
26.1.54	10·7	4·24	—	12,350	—
21.7.54	—	—	—	—	62 (Westergren)
29.11.54	12·5	4·42	42	8,450	28 (Wintrobe)
16.2.55	14·9	4·15	41	10,250	40 (Wintrobe)
18.2.55	13·0	—	38	7,200	—

in hospital with rest, penicillin and salicylates. Five and a half months later she first came to the University College Hospital saying that for ten days she had had pains in the neck, hips, knees, ankles and left hand, in that order. She was found to have a temperature of 100 degrees Fahrenheit and the first and second metacarpo-phalangeal joints of the left hand were swollen, tender, slightly reddened and hot. She was advised to rest in bed at home and

TABLE II
BIOCHEMICAL EXAMINATIONS OF BLOOD
(All figures are in milligrammes per 100 millilitres)

Date	Calcium	Uric acid	Urea	Phosphorus
1.2.54	14	—	—	—
29.11.54	10·5	5·0	54	—
8.12.54	—	3·6	19	4·4
16.2.55	11.5	3·3	—	6·0

given aspirin, 30 grains, to be taken four times daily. A week later there was considerable improvement. Her temperature was normal. There was still some swelling of the first and second metacarpo-phalangeal joints of the left hand and some swelling on the back of the left carpus. Pain slightly limited movement of the left wrist although the wrist joint itself did not appear to be involved. Just over three weeks from the start of the attack she had recovered. Apart from the joint condition, physical examination showed the patient to be normal.

Six months later pains returned to the right thumb and wrist, then to the left knee and to several finger joints. The pains were severe enough to keep her awake. She was admitted

to hospital with mild pyrexia but no other abnormal findings apart from the joints. The most severely affected of these was the right wrist. She would permit no movement of the wrist and there was redness of the skin over the joint. There was considerable pitting oedema

FIG. 1
Right and left shoulders.

FIG. 2
Right elbow.

FIG. 3
Right hand.

about the wrist and on the back of the hand. The fingers of the right hand ached and were held in moderate flexion and the soft tissues of the fingers were slightly swollen. The right elbow was painful, swollen, and held at a right angle. Though she complained of pain in the

knees, they were normal on examination. Treatment was confined to rest in bed and a few doses of salicylates were given. The condition subsided abruptly and a week after the onset the joints were normal on examination.

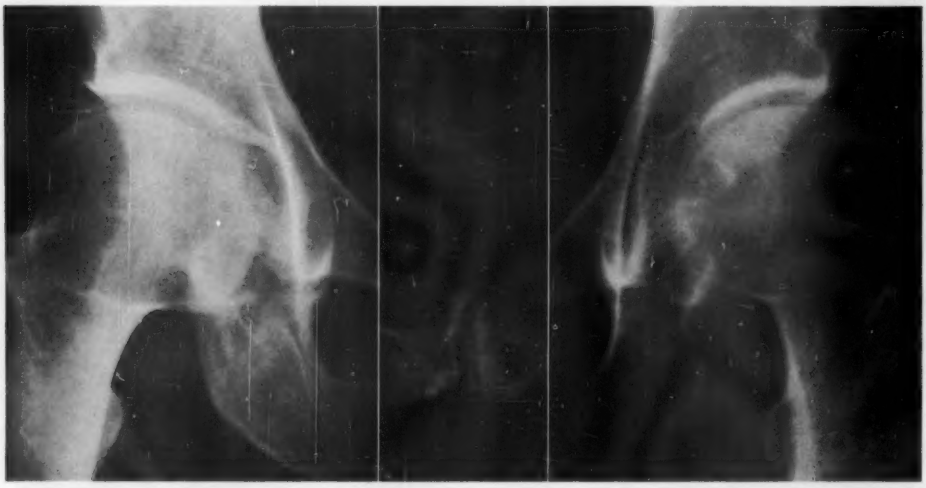

FIG. 4
Right and left hips, and interpubic joint.

FIG. 5
Right and left knees.

A gynaecological examination showed that she had thickened Bartholin's glands and had undoubtedly had gonorrhoea but there was no evidence of serious residual pathology in the pelvis.

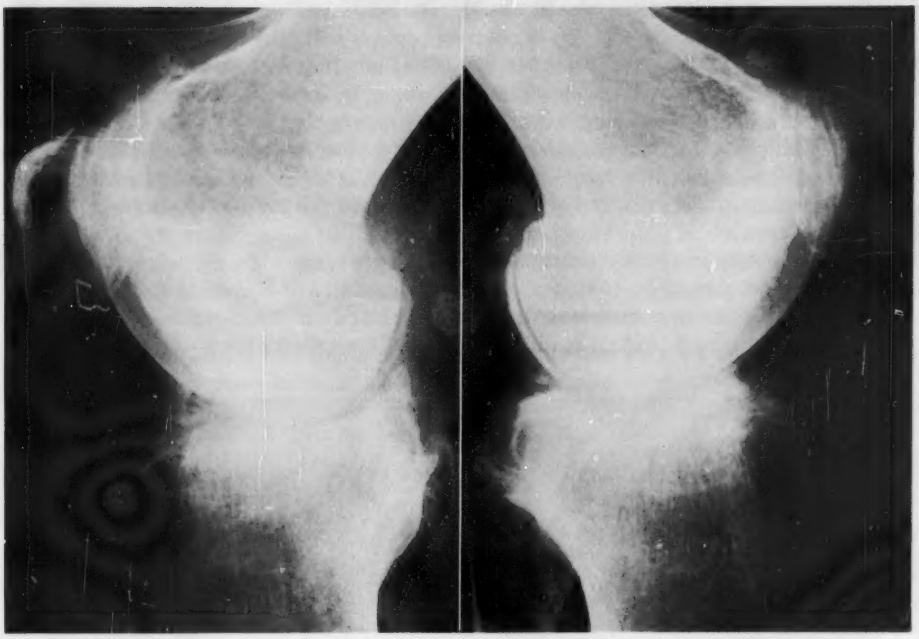

FIG. 6
Lateral radiographs of knees.

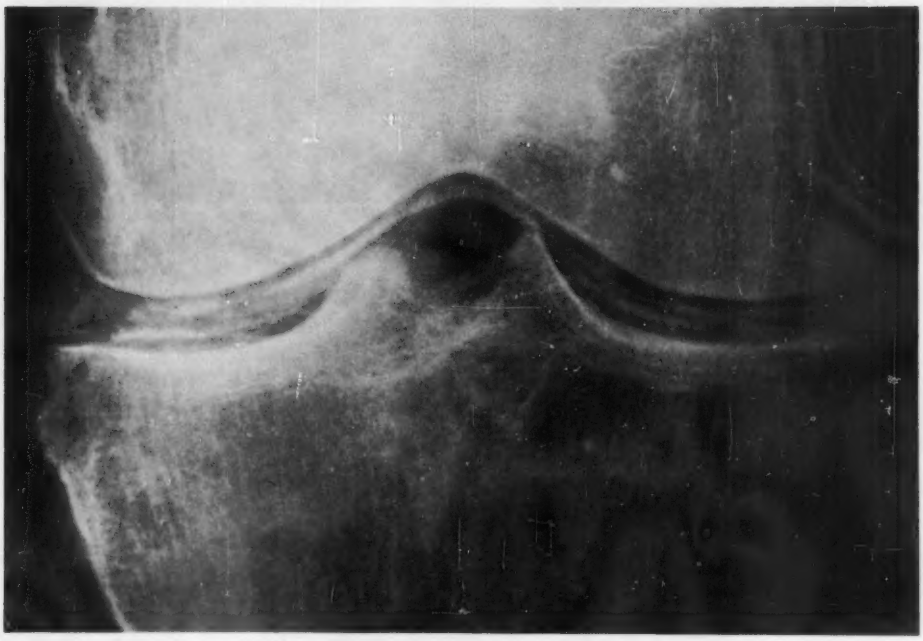

FIG. 7
Detail radiograph of knee.

When last seen a month later she was in good health and was free from symptoms in the joints.

Investigations—In 1952 a trace of protein had been found in the urine with pus cells in the centrifuged deposit and staphylococcus albus on culture. While she was under our observation no significant urinary abnormality was detected.

The Kahn test for syphilis, the V.D.R.L. test, the Kolmer-Wassermann test, the lymphogranuloma venereum complement-fixation test, and the gonococcal complement-fixation test were all negative. The red blood cells did not show any characteristics of sickle-cell disease.

Two chest radiographs and electrocardiographs were normal.

Table I gives the results of studies on the blood cells. The first three readings indicate an anaemia. On the three occasions that the white blood cell count was above 10,000 per cubic millimetre the count was made within two days of the patient's being admitted to hospital

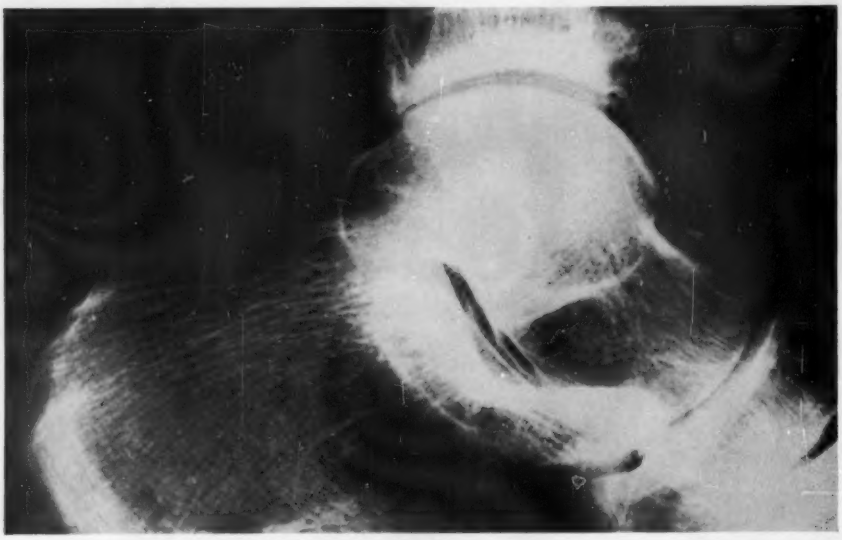

FIG. 8
Left ankle.

in an acute attack and while she still had fever. The readings for the white blood cells below 10,000 per cubic millimetre were all taken when the patient was well or past the acute phase. Differential white blood cell counts were normal or, with the raised counts, had an increase in the polymorphonuclear neutrophil cells. The two higher sedimentation rate readings occurred during acute phases. The figure of 28 was obtained when the patient was well.

Table II gives the results of some investigations of the blood chemistry. The serum calcium was once raised and this was at a time when the patient was having treatment in hospital but when the acute attack had passed off. The blood urea and the blood uric acid were once raised on an occasion when the patient was, in fact, without symptoms.

Radiological findings—Calcification was first seen over the surfaces of the joints of the hands and over the humeral heads (seen in a routine chest film). All the large joints of the upper and lower limbs were then found to be similarly affected (Figs. 1 to 8). The calcification was seen as a thin linear deposit on the articular surface and separated from the articular bone cortex by a narrow translucent zone. The contour of the articular bone cortex was not eroded or deformed and there was no change in the "joint-space" distance between the

adjacent bony surfaces. The calcified surfaces were clearly seen to be in contact with each other at many sites, suggesting that the calcium lay in or on the superficial layers of the hyaline cartilage of the articular surfaces. In the hands and feet the deposition was less extensive in the peripheral joints but was fairly extensive over the carpal and tarsal bones. Calcium was present over the whole articular surfaces of the shoulders, elbows, hips and knees. Bone density was normal with no evidence of any demineralisation.

Calcification was also visible in the fibrocartilage discs of the symphysis pubis, knee, and ulnar-carpal joints. It could not be seen in the intervertebral discs or articular facets of the spine, nor in the sacro-iliac joints though, had it been in the latter in only a thin layer, the density of the overlying soft tissues might have obscured it. The calcification did not alter over the period of observation of eight months. Comparison of recent radiographs with those taken a year previously at the Kingston Public Hospital showed no change.

Conclusion—Calcification was found in the fibrocartilage discs and on the hyaline articular cartilage surfaces of many joints, associated with intermittent fever, joint pain and swelling, but with otherwise normal physical findings and blood studies. No perceptible radiological changes developed during or after acute attacks of arthropathy.

DISCUSSION

Calcification occurring in the fibrocartilage discs alone is relatively common, but is not associated with pain or with calcification of the hyaline cartilage surfaces. Calcification in the joint synovial membranes has been described in association with hyperparathyroidism by Keynes and Taylor (1933). The distribution of calcification is not the same in our case, nor is there evidence of disturbed calcium metabolism.

The adjective " asymptomatic " used by Edwards and Davis (1953) for this condition seems inadvisable as the pain was severe enough in our case to keep the patient awake, and to cause her to seek medical aid and to be admitted to hospital. It is certainly remarkable, with such unchanging radiological appearances, that the symptoms should sometimes be confined to so few joints at a time and that the acute phases should be so transitory.

The cause of this condition is unknown, but it is suggested that the calcium deposition is a result of repeated attacks of a mild, acute arthritis of unknown etiology causing calcium deposition in the fibrocartilage articular discs and calcium to be laid around or over the superficial layers of hyaline cartilage as Edwards and Davis surmised. Otherwise the joints are remarkably normal and the patient is well after the acute phase has subsided, suggesting that the articular surface cannot be roughened or its function disturbed in spite of the persistent layer of calcium.

SUMMARY

1. Idiopathic calcification of articular cartilages is described in a Jamaican woman of thirty-one years who had intermittent joint pains for ten years and who had evidence of past gonococcal infection. She was otherwise normal.
2. The etiology of the condition is unknown.
3. Previous literature is reviewed.

Our thanks are due to Professor E. K. Cruickshank in whose ward the case was studied, and to the Kingston Public Hospital, Jamaica, for kindly lending us their notes and radiographs of the patient.

REFERENCES

EDWARDS, D. A. W., and DAVIS, S. (1953): Primary Asymptomatic Calcification of Articular Cartilage. Journal of Bone and Joint Surgery, **35-B**, 434.

HARMON, P. H. (1944): Degenerative Calcification in Articular Cartilage of the Knee. Journal of Bone and Joint Surgery, **26**, 838.

ISRAELSKI, M. (1931): Meniscus Calcification. American Journal of Roentgenology, **25**, 85.

KEYNES, G., and TAYLOR, H. (1933): A Case of Parathyroid Tumour. British Journal of Surgery, **21**, 20.

WOLKE, K. (1935): Über Meniskus- und Gelenkknorpelverkalkungen. Acta Radiologica, **16**, 577.

MYELOGRAPHY IN THE LUMBAR REGION WITH WATER-SOLUBLE CONTRAST MEDIUM

TH. BOESMAN, ANNAKLINIEK, LEIDEN, HOLLAND

Arnell and Lidström (1931) described myelography of the lumbar region with water-soluble contrast medium, but difficulties in finding the correct medium delayed the success of the method. Arnell reviewed the subject again in 1944. Werf and Prick (1949) improved the technique. In the Annakliniek at Leiden about ninety myelographies have been done with " Leo U,"* a 20 per cent solution of sodium monoiodomethanesulphonate. Seventy-three cases have been observed long enough to give an impression of the value of the method.

FIG. 1

Positive myelographs in a case of herniated nucleus pulposus at the L.4–5 level.

Technique—The patient lies on the side on which the lesion is suspected, with his back turned to the screen, the arms along his head. The table is tilted 20 degrees, the head on the higher side. The spinal canal is entered with a fine needle at the level of the L.3–4 interspace.

The pressure is measured and the reaction to the Queckenstedt test determined. About 10 cubic centimetres of cerebro-spinal fluid is collected for examination. One and a half cubic centimetres of 10 per cent aethocaine is now injected (Ephedrine is kept ready for injection in case of collapse) and after fifteen minutes 15 cubic centimetres of " Leo U " are injected slowly, leaving the needle in place. Four radiographs are taken, with the tube directed horizontally. The projections are: 1) lying on the side on which the lesion is suspected;

* H. Lundbeck and Co.

2) rotated 30 degrees forward; 3) rotated 45 degrees backward; 4) fully prone. When the films have been taken about 10 cubic centimetres of fluid are allowed to escape, and the needle is removed. The patient should rest for two hours half sitting in bed and then for twenty-four hours flat in bed. There has been no instance of serious ill-effect.

Results—Out of the seventy-three cases studied operation was later performed in thirty-three. In these thirty-three cases the myelography was positive twenty-six times and the operative findings were also positive (herniated discs in twenty-four cases, thickened ligamentum flavum in two cases). In three cases the myelography was doubtful but the operation findings were positive. In one case the myelography was negative and the operation findings were negative. In three cases the myelography was negative but the operative findings were positive. This represents an error of 9 per cent. Of the forty cases in which operation was not performed there was a complete conformity between the clinical findings and the myelography in twenty-two, and contradictory findings in three. This represents an error of 7·5 per cent.

In the fifteen cases in which there was no full accordance, the myelography saved the patient in eleven cases from an unnecessary operation because, on the evidence of the myelography, conservative treatment was successfully established. (A success means that a man has been fully at work again for a year or that a woman has no complaints in doing her normal work at home.) Examples of the myelographs obtained are shown in Figure 1.

The combination of accurate clinical investigation, neurological consultation, in most cases a trial of conservative treatment, and myelography proved so reliable that in this series of thirty-three operations for suspected herniated nucleus pulposus there was only one negative finding and twice a thickened ligamentum flavum. When a genuine herniation has been found the result of the operation has been very satisfactory.

CONCLUSIONS

The follow-up of these seventy-three cases suggested the following conclusions:

1. The clinical signs alone are not always sufficient to make the diagnosis of herniated nucleus pulposus with sufficient accuracy.
2. When positive, myelography was reliable as a means of localising the hernia.
3. In doubtful cases in which conservative treatment failed a clearly positive myelography turned the scale for a well-indicated operation.
4. In doubtful cases a clearly negative myelography has often rightly been a contra-indication for laminectomy.
5. No serious complication from the use of water-soluble contrast medium for myelography has been encountered.

REFERENCES

ARNELL, S., and LIDSTRÖM, F. (1931): Myelography with Skiodan (Abrodil). Acta Radiologica, **12**, 287.
ARNELL, S. (1944): Weitere Erfahrungen über Myelographie mit Abrodil. Acta Radiologica, **25**, 408.
WERF, J. T. vander, and PRICK, J. J. (1949): Myelographie met snel resorbeerbare contrastmiddelen ter vaststelling ener hernia nuclei pulposi. Nederlandsch Tijdschrift voor Geneeskunde, **93**, 853.

PARAPLEGIA DUE TO HYDATID DISEASE

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In Great Britain hydatid disease is uncommon, and instances of hydatid cysts causing pressure on the spinal cord or nerve roots are rare. There appear to be only fifteen published cases in the medical literature in this country. The last review of spinal hydatid disease seems to be that of Colman (1899). The three new cases here recorded may therefore be of interest.

As an illustration of the rare occurrence of hydatid disease in Great Britain, Table I shows the deaths from this disease during the years 1921-50.

TABLE I

DEATHS FROM HYDATID DISEASE IN GREAT BRITAIN FROM 1921–50

Deaths	1921–30*	1931–40	1941–50
Total	296	260	172
Per million of population	6·68	5·63	3·58

* Figures of liver desease only

The rarity of the disease in the spine is also indicated by figures from Australasia, where a " hydatid registry " was commenced in 1930. In the succeeding eighteen years there were twenty-four cases of hydatidosis of the spine, representing 1·2 per cent of all cases of hydatid disease (Woodland 1949). It is not recorded how many of these cases were complicated by paraplegia, nor was any mention made of paraplegia from extra-osseous hydatid disease.

It is likely that the number of cases in which the spinal column is attacked will always be small in view of the usual distribution of hydatid cysts in man, as recorded in the Hydatid Registry of the Royal Australasian College of Surgeons (Barnett 1945) (Table II).

TABLE II

DISTRIBUTION OF HYDATID CYSTS IN MAN

Site	Per cent of all cases	Site	Per cent of all cases
Liver . .	63·3	Kidney . .	2·1
Lung . .	24·5	Spleen . .	1·3
Muscles. .	4·6	Brain . .	0·9
Bone . .	2·6	Other sites .	0·8
(Vertebrae 1·2)			

PATHOLOGY

Hydatid disease in the peripheral organs begins as a single primary cyst. This may contain daughter cysts which are regarded as the parasite's defensive reaction to trauma. Rupture of a cyst into muscular tissue may be followed by a crop of secondary hydatid cysts originating from daughter cysts, scolices or brood capsules. Sometimes these small secondary cysts may be forced by muscle movement some distance along connective tissue planes.

Hydatid infection in bone is always primary (Dew 1928). Secondary erosion of bone by an extra-osseous cyst may occur, but the cyst does not infiltrate into the bone substance. Owing to the peculiar structure and the resistant nature of bone, true hydatid disease in bone differs from hydatid disease elsewhere in two respects—namely, exogenous vesiculation occurs and there is no adventitious layer (ectocyst). As the embryo grows, some absorption of bone occurs with dilation of the bony space in which the parasite lies, but this occurs very slowly. The parasite grows along the line of least resistance, along the bony canals, to form a diverticulated type of "cyst." These cysts do not contain fluid but are composed of solid masses of hyaline material surrounding a central nuclear mass. The diverticula may become separated from the parent cyst—the so-called "beading-off" of secondary cysts. When "beading-off" occurs into the surrounding soft tissues, the secondary cysts assume the typical univesicular type of growth. Avascular necrosis may occur in the more central part of the bony lesion, leading to cavitation or pathological fracture.

When the disease occurs in or near the vertebral column the spinal cord may be compressed either by a cyst whose primary situation is in the spinal canal or by cysts arising from primary disease of the vertebrae or paraspinal tissues, which have secondarily invaded the extradural space.

Classification—Five types will be recognised: 1) Primary cyst in the spinal cord; 2) intradural cyst; 3) extradural cyst; 4) hydatid disease of the vertebrae; 5) paravertebral hydatid disease.

PREVIOUSLY REPORTED CASES

PRIMARY CYST IN THE SPINAL CORD

No case has been reported, but theoretically such cysts can occur.

INTRADURAL CYST

No case of primary cyst has been reported in Great Britain but a typical case was reported in South America (Allende and Luque 1935). The cyst was single, it occurred in a young subject, symptoms appeared early, and laminectomy with removal of the cyst led to almost complete recovery.

Instances have been reported of small multiple intradural cysts, but these were certainly secondary, as in Case 16 in the series reported later.

EXTRADURAL CYST

The primary cyst commonly occurs in young people and arises in the loose fatty extradural tissue. It is single and soon assumes an elongated shape as it grows along the spinal canal, and gradually produces increasing cord compression. The following recorded cases illustrate the clinical picture.

Reported Cases

Case 1 (*Colman* 1899)—Boy aged ten years. History of pain in left shoulder for three months, weakness in the left arm for three weeks, and weakness in the left leg for one week. Soon after admission to hospital he lost the power of movement in the right arm and two days later in the right leg. He then developed flaccid paralysis of the arms and spastic paralysis of the legs. At post-mortem examination, a year later, a hydatid cyst, one and a half inches long, was found lying extradurally to the left of the cord at the level of C.2–4 vertebrae. There was also a hydatid cyst in the liver.

Case 2 (*Rogers and Tudhope* 1938)—Girl aged nine years. History of pain in the thighs and lower back for eight months, and of flaccid paralysis of the legs with sensory loss for one month. Laminectomy was performed and a single extradural hydatid cyst, two inches long, was found at the level of the second lumbar vertebra. Complete recovery in three months.

Case 3 (*Ransom and Anderson* 1891)—Man aged forty-two years. History of pain in the back and shooting pains in the legs to the soles of the feet for eighteen months. Symptoms severe at first but after four months became less severe and intermittent, then returned to their severity after a further twelve months. Weakness in the legs for one month, flaccid paraplegia for two weeks, with difficulty

in passing urine. Laminectomy T.11–L.2 revealed nothing abnormal. Post-mortem examination showed a single extradural cyst attached to the lamina of T.10 vertebra. There were two cysts in the right erector spinae muscles.

This type of cyst, if diagnosed or explored early, is particularly amenable to surgery, in that it can be removed completely and recurrence is unlikely (Case 2).

If the cyst is allowed to continue growing it may make its way out of the canal by eroding the laminae or through the intervertebral foramina, and enter or rupture into the thorax or spinal muscles. If rupture occurs the patient may experience a temporary relief in symptoms (Case 3).

HYDATID DISEASE OF THE VERTEBRAE

Paraplegia occurring as a complication of hydatid disease is most frequently due to hydatidosis of the vertebral column.

The disease may begin in the bodies, pedicles or laminae, and spreads in the cancellous tissue in the same way as in other bones. The articular cartilage does not offer much resistance to the spread of the disease, and the intervertebral discs, although more resistant, are also invaded and allow spread to adjacent vertebrae (Woodland 1949).

Dew (1928) stated that usually the disease remains confined to the bone for years, but sooner or later extra-osseous extension takes place. Often the disease spreads to the paravertebral muscles, and fairly large multiple cysts may develop in them. Cysts may also extend into the mediastinum, retroperitoneal tissues or extradural space; the latter give rise to compression of the spinal cord.

Reported Cases

Case 4 (*Ogle* 1860)—Specimen at St George's Hospital of a hydatid cyst within the spinous process of C.7, projecting upon the spinal cord and producing symptoms " not unlike cancer." Few cysts in the cancellous structure of the vertebrae.

Case 5 (*Moxon* 1871, *described by Fagge* 1888)—Woman aged fifty-eight. Pain in side for eleven months, paraplegia for six weeks. Post-mortem examination showed a multilocular hydatid cyst to the left of the spine, which made its way into the canal " through " L.2 and L.3 vertebrae and compressed the cord but did not penetrate the dura.

Case 6 (*Maguire* 1888)—Boy aged sixteen years. History of pain and weakness in arms for three years, spastic paraplegia for two weeks. Died three weeks after admission to hospital with symptoms of meningitis. Post-mortem examination revealed many small extradural cysts between C.7 and T.6 vertebrae, and some cysts embedded in the bone of the vertebral arches. The meninges were congested.

Case 7 (*Barrs and Trevelyan* 1899)—Man aged fifty-two years, with symptoms of acute myelitis. At post-mortem examination the cancellous tissue of the vertebrae was extensively occupied by minute cysts. Extradural cysts were found between T.1 and L.2 vertebrae.

Case 8 (*Theobalds* 1909)—Male aged seventy-five years. History of having thirteen worms removed from abscess over sacrum years before; paraplegia with bowel and bladder involvement for seven months. Post-mortem examination showed a swelling in the right lumbar region to be a suppurating hydatid cyst extending into the right sacrospinalis muscle as high as L.2, and into the pelvis to the left of the sacrum. L.3 vertebra was carious with cysts in the bone.

Case 9 (*Ruskin* 1939)—Man aged twenty-seven years. History that hydatid cysts were removed from left side of neck three years previously; paraesthesia and weakness on the left hand for three months, spastic paraplegia for two weeks. Radiographs showed erosion of C.7 and T.1 vertebrae. At laminectomy three extradural cysts were removed at level of T.1. Patient died.

Case 10 (*Horsley* 1897)—" . . . a man with symptoms of compression at the origin of the third lumbar nerve. On opening the spine at the twelfth dorsal vertebra we found it was due, not to a new growth, but to multiple hydatid cysts of the vertebral column." *Gowers* (1899), referring to this case, stated that the damage had been too great to allow recovery of the paralysis in the thigh and hip muscles.

Case 11 (*Tytler and Williamson* 1903)—Woman aged twenty-seven years. History of removal of a hydatid cyst from the inferior angle of the left scapula four years previously; mid-thoracic pain for two months and flaccid paraplegia with bowel and bladder involvement for one month. There was a subcutaneous cyst to the left of T.3 and T.4 spines. At laminectomy fifteen extradural cysts were removed. Two years later a cyst in the scar was drained, and two and a half years later the patient still had a spastic paraplegia but sensation and bowel and bladder function were normal.

Case 12 (*Rogers* 1938 *and Wolfe* 1943)—Boy aged ten years with spastic paraplegia for four months. At laminectomy an extradural cyst at T.6 level was removed. Complete recovery in three months. Six years later a gradually increasing kyphosis with paraplegia occurred. Laminectomy at T.3–4 level revealed a mass of hydatids arising in the bodies of the vertebrae and extending into the spinal canal and pleural cavity. No recovery after seven months. The cord was re-explored and freed from the scar tissue. Patient died later.

The prognosis in vertebral hydatid disease appears hopeless as regards complete cure. Laminectomy and removal of cysts and debris from the spinal canal may relieve the compression symptoms temporarily but recurrence of symptoms is the usual fate (Cases 10 to 12).

The cases reported by Gowers (1899) and by Tytler and Williamson (1903) cannot be regarded as cured because they were not followed up for long enough to show the ultimate fate of the patients.

It is possible that infection occurs in childhood, but because of the slow growth of the hydatid cyst in bone the symptoms do not usually occur before adult life, when destruction of the bone leads to vertebral collapse, or extra-osseous extension causes a palpable tumour or cord compression.

The average age at death in the cases reviewed was forty-one years and the average duration of life after onset of symptoms was five years.

PARAVERTEBRAL HYDATID DISEASE EXTENDING INTO THE SPINAL CANAL

A hydatid cyst, primarily in the mediastinum, retroperitoneal tissues or spinal muscles, may erode the vertebrae by pressure or may extend or rupture into the extradural tissues through the intervertebral foramina.

It may be difficult to differentiate this type of case from the primary extradural hydatid which makes its way out of the canal. However, when the size and position of the cysts and the time of onset of the nervous symptoms in relation to the other symptoms and signs are taken into consideration, the types can usually be differentiated.

Reported Case

Case 13 (*Brailsford* 1931)—A large hydatid cyst of the superior mediastinum eroded the vertebral bodies and caused pressure on the cord, and eventually ruptured into the spinal canal.

UNCLASSIFIED CYSTS

The location of the primary cyst in the following two cases could not be determined from the published data.

Case 14 (*Morgan* 1877)—Woman with symptoms and signs of caries of the lumbar vertebrae. Post-mortem examination showed the spinal cord to be atrophied in its last one and a half inches to the size of a crow quill from pressure of a hydatid cyst. The cyst occupied the spinal canal to the right of the cord and, escaping through T.10–11 foramen, swelled out into a large elongated mass which entirely filled the hollow of the abdomen to the right of the spine.

Comment—This might well have been primarily an extradural cyst. On the other hand, the description could be compatible with cysts in the paravertebral tissues which secondarily penetrated through T.10–11 foramen (compare Case 16).

Case 15 (*Murchison* 1877)—Woman aged forty years with symptoms of paraplegia and retention of urine. Post-mortem examination showed the pleura to be separated from the ribs and sides of the vertebral bodies by two hydatid cysts, one on each side. The spinal cord at this place is considerably smaller than elsewhere.

Comment—The primary disease may have been in a thoracic vertebra or it may have been an extradural cyst which had made its way out of the canal through the intervertebral foramina on either side (compare Case 18).

NEW CASE REPORTS

In 1952, while attached to the Royal Infirmary, Liverpool, I had personal experience of a case of paravertebral hydatid disease which terminated in paraplegia. The sacrospinalis muscle was the primary site of the disease.

Case 16 (*Mr Norman Roberts's case*)—Man aged forty years who had been in close contact with dogs all his life complained of low back pain and right-sided sciatica for eleven weeks.
History—Ten years ago, swelling right lumbar region, occasional tenderness, fluctuated in size. Symptoms disappeared with physiotherapy. One year ago attack of low back pain with swelling in right lumbar region. Symptoms disappeared after physiotherapy.

FIG. 1

FIG. 2

Case 16. Figure 1—Hydatid cyst in the sacrospinalis muscle. Figure 2—Multiple hydatid cysts in the spinal canal.

Examination—Patient distressed; flat, rigid lumbar spine, tilted to right. Straight leg raising right 30 degrees, left 50 degrees. Right knee jerk diminished. Radiographs normal. Diagnosed as a disc lesion.
Treatment—Bed rest followed by plaster jacket. Temporary improvement, then symptoms recurred. Subsequent radiographs showed generalised osteoporosis of lumbar spine. Blood chemistry and urine normal. Symptoms responded to weight traction and plaster jacket. Three months later the patient was readmitted with a complaint of three weeks' difficulty in defaecation, one week's difficulty in micturition. Previous day had pain in thoracic region. On examination, semi-conscious, evidence of loss of weight, bladder grossly distended, weakness in legs (tendon jerks not elicited, plantars equivocal), neck rigidity. Blood urea normal. Lumbar puncture—bloodstained fluid, low pressure. After epileptiform attacks the patient died.

Post-mortem examination—A large multilocular hydatid cyst occupied the right sacrospinalis muscle from T.12 to L.5 (Fig. 1). The main body of the cyst was occupied by daughter cysts, and it had grown in an infiltrative manner, passing through the intervertebral foraminae in the lumbar region. There were a number of small cysts lying extradurally up to the level of T.12. Posteriorly, the continuity of the dura was lost, and some small cysts were found in the subarachnoid space in the lumbar region (Fig. 2). Brain and meninges normal; other organs normal.

Mr Sutcliffe Kerr told me of a patient on whom he operated during the war years. This was a case of hydatidosis of the vertebral column which presented with paraplegia. Unfortunately the case notes and radiographs cannot be traced and re-examination of the patient has not been possible.

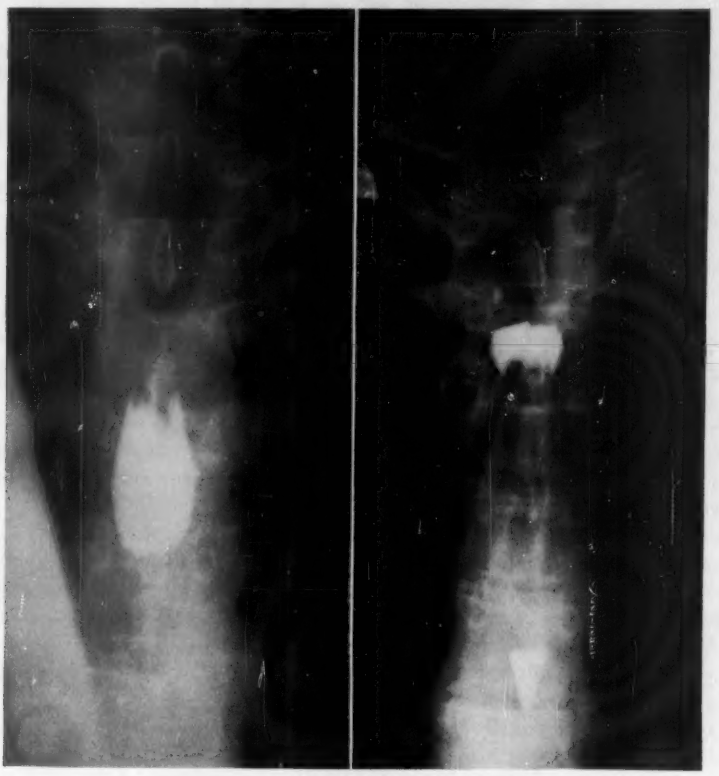

FIG. 3
Case 18—Myelographs showing a space-occupying lesion (hydatid cyst) at the level of the fourth thoracic vertebra.

Case 17 (*Mr Sutcliffe Kerr's case*)—Middle-aged female with symptoms and signs of a spastic paraplegia. Radiological examination showed lesions in some thoracic vertebrae and adjacent ribs, which were diagnosed as being due to hydatid disease. Laminectomy was undertaken to relieve the symptoms and multiple extradural cysts were found and removed. She left hospital in good general health.

The following case of an extradural hydatid cyst giving rise to paraplegia is under the care of Professor Norman Dott at the Royal Infirmary, Edinburgh. It illustrates the excellent results and good prognosis which follow timely surgery in this type of case.

Case 18 (*Professor Norman Dott's case*)—Man aged thirty-nine years. First admitted to hospital in 1948 complaining of difficulty in walking for three months.

History—Three months ago had a minor injury to back. Noticed his legs felt stiff and difficult to control; occasional "jerking in bed." For five weeks urgency and frequency of micturition, desire to defaecate with little result. No history of contact with dogs.
Examination—Signs of mild spastic paraplegia. Impairment of sensation below eighth rib. Tenderness over T.6 spine. *Lumbar puncture*—Pressure 200 millimetres, rapid rise on jugular vein compression but slow fall. Protein 90 milligrams per cent.
Radiographic examination—Thinning of pedicles T.4. Myelography—Block between lower border T.3 and upper border T.5 (Fig. 3).
Operation—Laminectomy, with total removal of T.4 lamina, and partial removal of T.3 and T.5 laminae. A hydatid cyst was found lying in an excavation in the vertebral bodies, anterior to the cord and extending in dumb-bell form through the intervertebral foramina on either side. The cord was compressed and indented from the front, and the T.4 nerve roots were stretched over the lateral extensions of the cyst. The operation field was draped off, the cyst opened and its contents (including daughter cysts) were removed by suction. The lateral extensions of the cyst were freed with difficulty from the intervertebral foramina, the right T.4 nerve root was severed extrathecally and used to rotate the cord gently to facilitate removal of the central part of the cyst wall from the anterior surface of the dura. The cord now lay like a bridge across the excavation in the vertebral bodies. Formalin was not used for fear of damage to delicate structures. The wound was closed, completing the operation.
Histological examination—Echinococcal cyst, complete with brood capsule and two rows of hooklets.
Progress—Within four weeks the patient was walking normally. No bowel or bladder trouble. Six years later he was well, and had no recurrence of any symptoms.

TREATMENT

In the absence of any efficient medicinal treatment, complete surgical extirpation of the parasite is the only possible policy. This is more easily accomplished before the primary hydatid cyst has ruptured, and therefore successful treatment depends on the early recognition of the disease.

Extraspinal hydatid disease should be dealt with radically by surgery and the cavities swabbed out with 5 per cent formalin to kill any live parasitic tissue that may remain. Minor symptoms and signs may be present for years in extraspinal disease, and if cord compression supervenes it is a late complication (Case 16).

In osseous hydatidosis, nothing less than complete excision of the affected bone is curative. Curettage and formalinisation (Dew 1928) and deep x-ray therapy (Coley 1932, Howorth 1945) have both proved ineffective. When symptoms of vertebral disease occur extra-osseous extension has usually taken place and extirpation of the disease may be impossible.

As regards the management of a case of cord compression from primary or secondary hydatid cysts, Professor Dott has kindly sent me the following observations on the surgical treatment.

1. One can only occasionally *suspect* the presence of this condition, from the history and background of the patient, from the presence of cysts elsewhere, from the Casoni test, and possibly from the radiographic appearance of the bone (Case 17).

2. With knowledge of the above, recognition of the disease at operation (the usual laminectomy for spinal tumour) is very important.

3. The treatment then is like that of these cysts elsewhere in the body, thus: carefully drape the wound. Very carefully remove all the cysts (suction is particularly useful): great care must be taken to prevent the dissemination of small daughter cysts and scolices in the wound. The dura should also be opened to allow careful intradural exploration, as not infrequently intradural cysts are present. Special care must be taken to remove any intervertebral foraminal extensions. In contradistinction to operative treatment for this disease elsewhere in the body no fixative agent such as formalin or alcohol should be used, because of the obvious danger to the nervous tissues.

4. Careful follow-up is necessary to check any local recurrence and to observe if any hydatids are developing elsewhere.

SUMMARY

1. Cases of hydatid disease causing paraplegia since 1860 in Great Britain have been briefly reviewed and three recent cases have been added.
2. The types have been classified, the clinical pictures outlined and the treatment discussed.

It is a pleasure and a privilege to thank Professor Norman M. Dott for his great kindness in allowing me to use his clinical records and radiographs, and for his contribution to the discussion on treatment. I am most grateful also to Mr Sutcliffe Kerr for permission to record his case and to Mr Norman Roberts, whose encouragement made this paper possible. To Professor Bryan McFarland and Mr Robert Roaf my thanks are due for their advice and most helpful criticism. The pathological specimens were prepared by Dr H. T. G. Strawbridge of the University of Liverpool. The Registrars-General of England and Scotland and the Welsh Board of Health kindly supplied me with statistics.

REFERENCES

ALLENDE, J. M., and LUQUE, O. (1935): Sindrome de compresión medular, por quiste hidático intradural. Boletines y Trabajos de la Sociedad de Cirugia de Buenos Aires, **19,** 283.

BARNETT, L. E. (1945): Hydatid Registry. Australian and New Zealand Journal of Surgery, **15,** 72.

BARRS and TREVELYAN (1899): Hydatid Disease of the Spinal Canal. British Medical Journal, **ii,** 1,354.

BRAILSFORD, J. F. (1931): Hydatid Disease in England. British Medical Journal, **i,** 133.

COLEY, B. L. (1932): Echinococcus Disease of Bone. Journal of Bone and Joint Surgery, **14,** 577.

COLMAN, W. S. (1899): Hydatid Cyst of the Spinal Canal causing Paraplegia. St Thomas's Hospital Reports, **28,** 361.

DEW, H. R. (1928): Hydatid Disease, p. 369. Sydney: The Australian Medical Publishing Company Limited.

DOTT, N. M. (1955): Personal Communication.

FAGGE, C. H. (1888): The Principles and Practice of Medicine. Second edition, Vol. **1,** p, 481. London: J. & A. Churchill.

GOWERS, W. R. (1899): A Manual of Diseases of the Nervous System. Third edition. Vol. **1,** p. 306. London: J. & A. Churchill.

HORSLEY, V. (1897): A Clinical Lecture on Diseases of the Spinal Cord Requiring Surgical Treatment. Clinical Journal, **9,** 177.

HOWORTH, M. B. (1945): Echinococcosis of Bone. Journal of Bone and Joint Surgery, **27,** 401.

MAGUIRE, R. (1888): Hydatids of the Spinal Canal. Brain, **10,** 451.

MORGAN, J. H. (1877): Report of Surgical Cases. St George's Hospital Reports, **8,** 533.

MURCHISON, C. (1877): Clinical Lectures on Diseases of the Liver. Second edition, p. 129. London: Longmans, Green & Co.

OGLE, J. (1860): Hydatids of the Omentum, Surface of the Spleen and Other Parts, Two of which Caused Perforation of the Diaphragm. Probable Rupture of Hydatid Cyst in the Abdominal Cavity During Life. Minute Characteristics of the Hydatid Formations. Transactions of the Pathological Society, **11,** 299.

RANSOM, W. B., and ANDERSON, A. R. (1891): Case of Echinococcus of Spinal Canal with Operation. British Medical Journal, **ii,** 1,144.

ROGERS, J. S. Y., and TUDHOPE, G. R. (1938): Hydatid Cyst of the Spinal Canal Successfully Treated by Operation. Archives of Disease in Childhood, **13,** 269.

ROGERS, L. (1938): Hydatid Disease. *In* Medical Annual, p. 253. Bristol: John Wright & Sons Ltd.

RUSKIN, L. (1939): Extradural Hydatid Cysts producing Paraplegia. British Medical Journal, **i,** 560.

THEOBALDS, A. F. (1909): A Note on a Case of Hydatid Disease of Lumbar Vertebra. Lancet, **i,** 1,048.

TYTLER, P., and WILLIAMSON, R. T. (1903): Spinal Hydatid Cysts Causing Severe " Compression Myelitis." British Medical Journal, **i,** 301.

WOLFE, H. R. I. (1943): Hydatid Disease in Wales. Lancet, **i,** 795.

WOODLAND, L. J. (1949): Hydatid Disease of Vertebrae. Medical Journal of Australia, **ii,** 904.

A METASTASISING ADAMANTINOMA OF THE TIBIA

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Since Fischer (1913) first described an apparently primary tumour of the tibia with the microscopic features of an ameloblastoma, a number of publications have established this interesting lesion as a rare but definite entity. Often preceded by trauma, the tumour grows slowly, has not hitherto responded to irradiation, and recurs after local removal. Amputation frequently effects a complete cure.

Earlier analyses of published reports led to its being regarded as non-metastasising, but a follow-up of these cases has revealed that regional and distant metastases, though delayed, are not uncommon (Baker *et al.* 1954).

The present case is considered worth recording for several reasons: 1) It is only the fourth case in the British literature; 2) a metastasis appeared in the chest wall twenty-two years after amputation; 3) this is the first instance in which a metastasis beyond the inguinal lymph nodes has been proved microscopically; and 4) the metastasis showed some response to telecobalt irradiation.

CASE REPORT

The patient, a male weigh bridge attendant, was first seen at the West London Hospital at the age of forty-two, complaining of a painful swelling in the upper third of the right leg. He had sustained a contusion at the same site a year earlier. Radiographs showed destruction of the tibia deep to the swelling, considered diagnostic of bone sarcoma, and supracondylar amputation was performed. The pathologist reported a spindle-cell sarcoma undergoing myxomatous change with cavity formation, and added: "It does not suggest a particularly rapidly growing neoplasm." Radiographs of the chest at that time showed no abnormality.

The patient remained well for nearly twenty-two years, and then developed a painful swelling over the ninth and twelfth ribs posteriorly. A biopsy at Fulham Hospital revealed an anaplastic malignant tumour, and the patient was referred to the Westminster Hospital. On examination the amputation stump was healthy and there were no palpable inguinal glands. Attached to the left lower ribs was a firm ovoid tumour measuring about eight inches by four. The axillary glands were not palpable. Radiographs revealed destruction of part of the eleventh rib, with a pathological fracture (Fig. 1). Comparison of the thoracic biopsy and the original tumour revealed similar microscopic characters, with small darkly staining cells arranged in masses with sharply defined spinous margins, and intercellular oedema, giving rise to the quasi-acinar formations that characterise the adamantinoma of the jaw (Figs. 2 to 5). Biochemical and haematological findings were normal. Telecobalt therapy was instituted using a 30 curie (20 centimetres source-skin distance) unit. Two fields, eight by six centimetres, were directed to the region of the eleventh left rib. A total tumour dose of 6,032 r. (maximum) and 4,524 r. (minimum) was given in forty-three days.

Eight months later the patient's general condition was excellent and the tumour was only a fifth of its original size. Radiographs showed that the rib lesion was calcified, but a round shadow had appeared in the lower lobe of the left lung.

DISCUSSION

The sole justification for calling these tumours adamantinomas is their histological appearance. We therefore feel free to exclude published cases unaccompanied by photomicrographs, or those that might be classed as anaplastic squamous carcinomas.

In the most recent review Baker *et al.* (1954) accepted twenty-seven cases, including three of their own. In the photomicrographs of their own Cases 2 and 3 the alleged epithelial strands are almost certainly osteoid foci of fibrous dysplasia, and we therefore accept their first case only. We also regard the cases of Pérochon and Veluet (1928), of Bell (1942), and of Mangalik and Mehrotra (1952) as not satisfactorily proven. Cases included in earlier series, which we also find unacceptable, are those of Maier (1900), Simon (1923), Nové-Josserand and Tavernier (1927), Casini (1935) and Vanek (1951). We accept the other twenty-two cases of Baker *et al.*, to which we add that of Hertz (1952) and our own case, bringing the total to twenty-four. We would, on histological grounds, include the case of Lederer and Sinclair (1954), but for the fact that these authors preferred to regard it as a malignant synovioma.

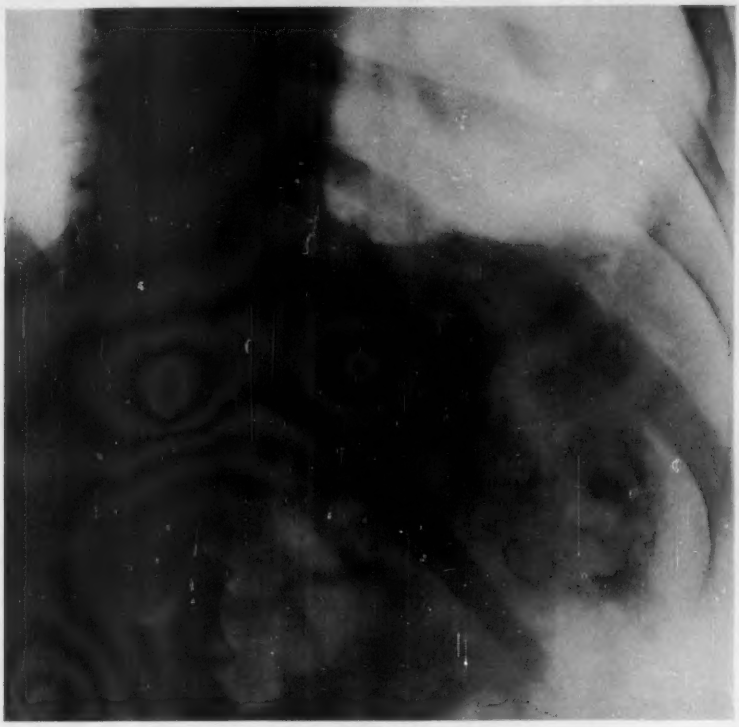

FIG. 1
Radiograph showing metastasis involving the eleventh left rib.

Of these twenty-four tumours, twenty-two have occurred in the tibia, one in the fibula (Baker *et al.* 1954) and one in the ulna (Anderson and Saunders 1942). In two-thirds of the cases the left tibia was involved. Fifteen of the patients were male. The age of the patient when first seen ranged from twelve to fifty-seven years.

Pathogenesis—Fischer (1913), who described the first case, believed the tumour to be a true adamantinoma, probably originating from a foetal cell rest during the intra-uterine period, because the potentiality of tooth-formation is limited to the stage in embryonic life during which tooth-germs are formed. The weakness of this concept is that it can neither be proved nor disproved. In recording the fourth case Ryrie (1932) noted that each tumour had been preceded by injury some months earlier, and suggested that in view of the close relationship of the bone to the overlying skin, tearing of the dermal appendages, followed by a haematoma,

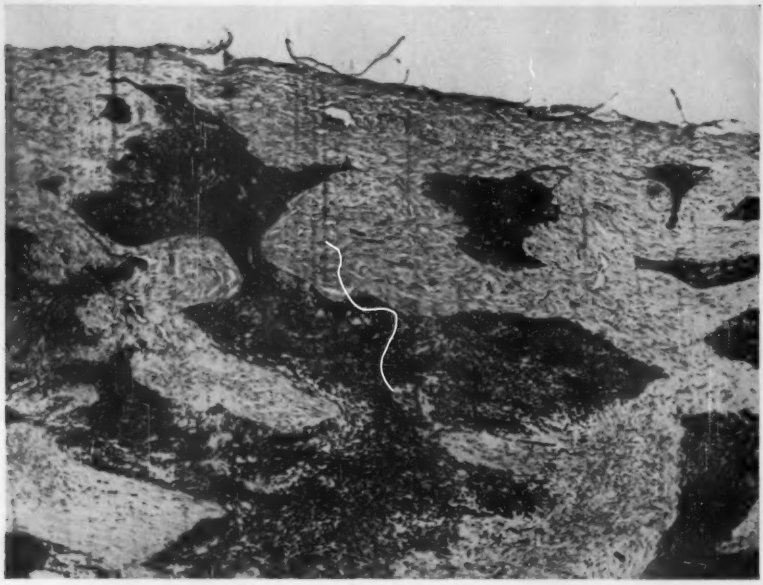

FIG. 2
Original tumour showing general pattern. (Haematoxylin and eosin, ×45.)

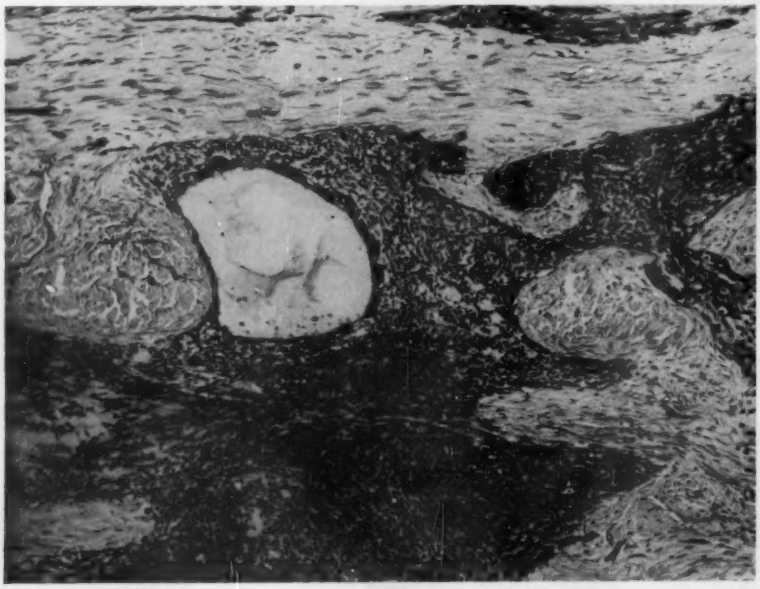

FIG. 3
Original tumour showing cyst formation. (Haematoxylin and eosin, ×75.)

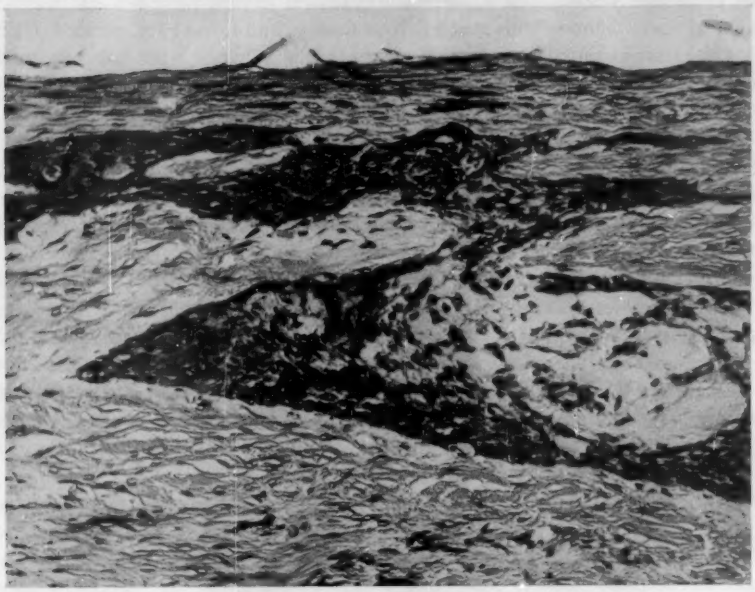

FIG. 4
Original tumour showing intercellular oedema simulating adamantinoma. (Haematoxylin and eosin, ×160.)

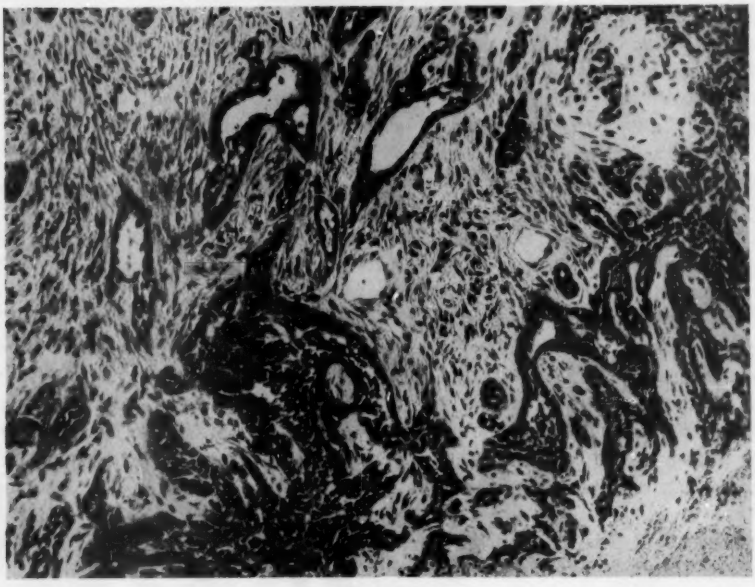

FIG. 5
Metastasis in chest showing typically adamantinomatous appearance. (Haematoxylin and eosin, ×125.)

caused a " thwarted repair " which, in the course of prolonged organisation, resulted in a tumour of basal cell type.

Neither of these theories finds much favour to-day, and it has been pointed out by Hicks (1954) that the tibia is singularly prone to minor injury. On the other hand several patients have been quite definite about the close relation between the growth and the site of injury. In some cases there was a lapse of months or years between the injury and the appearance of a lump, but in others the injury has been immediately followed by a painful swelling which persisted up to the time the tumour appeared.

Radiography of the tibia has often revealed a characteristic saucer-shaped depression of the bone below the tumour, suggesting erosion from the surface. Certainly the microscopic appearances, while not unlike the classical adamantinoma of the jaw, would do equally well for a basal cell carcinoma undergoing cystic degeneration. A number of growths have shown foci of squamous differentiation. It was suggested in another connection by King (1933) that post-traumatic epidermoid cysts resulted from a metaplasia of sweat-gland epithelium due to the presence of a subcutaneous haematoma. He was driven to this conclusion by the fact that many of his series of so-called " implantation " cysts occurred in the hands and fingers of manual workers who had sustained previous injury without breaking the skin. This concept offers some sort of answer to those who argue that the injuries preceding tibial adamantinomas have been often of a trivial nature.

In fact, the antecedent trauma has taken the following forms: contusion (9), abrasion (2), fracture (2), sprain (1), fall (1) and puncture wound (1). In four, however, a history of injury was doubtful, and in four others absent altogether. Still, the very frequency of tibial contusions and abrasions could well lead to their being completely forgotten by some patients. Perhaps the most formidable argument against the traumatic theory is the disparity between the rarity of the tumour (twenty-four cases in forty-two years) and the frequency of an injury that is the common lot of the human race.

In recent years a third theory has been advanced. In 1947 Lauche claimed that Fischer's original case was really a synovial sarcoma, and Hicks (1954) and Lederer and Sinclair (1954) independently arrived at the same conclusion regarding the others. Bennett (1947) and King (1952) described epithelial differentiation of synovial tumours, but after a study of some thirty-one synovial sarcomas in the Westminster Hospital series we remain unconvinced of the identity of the two growths, although occasional similarities are to be found in isolated microscopic fields. In the papers of Berger (1938) and of Tillotson *et al.* (1951) the synovial sarcoma is represented as a highly malignant tumour, although Wright (1952) described a relatively benign variety; but in none of these articles do the photomicrographs resemble the tibial adamantinoma. Boyd (1955) found the theory of synovial origin more palatable than those involving foetal rests or thwarted repair, but we feel that the concept of a synovial tumour arising in bone is not to be accepted without question.

Metastases—For many years it was imagined that the tibial adamantinoma was only locally malignant. Baker *et al.* (1954) dispelled this illusion by collating the post-operative history of earlier case reports, and seventeen of the twenty-four under review are available.

Nine patients were alive and well, with no evidence of metastases, fourteen to twenty-one years after amputation (five cases) and five to eighteen years after local excision or resection and bone grafting (four cases). As the amputation cases were published between 1931 and 1939, and those treated more conservatively between 1942 and 1954, the difference in duration of survival is not significant.

The other eight patients developed metastases, and seven died—two within a year from other causes (septicaemia, pulmonary embolism) and both had microscopically proved metastases in the inguinal lymph nodes. The other five lived from four to eleven years after the initial operation, and in all of these the evidence for pulmonary or skeletal metastases was clinical or radiological, there being no necropsy. The eighth patient—our own—developed

a metastasis in the chest twenty-two years after amputation, and this is the first case in which a distant metastasis has been proved microscopically to be of the same nature as the tibial primary.

Treatment—It is thus clear that the tibial adamantinoma is a slowly growing tumour of low grade malignancy. Recurrence after curettage or local excision is so frequent as to be virtually the rule; however, there is no guarantee that more radical measures will provide a cure. Six of the eight patients with metastases underwent amputation, in one case as the primary treatment, in four within seven to twenty-four months of the first operation, and in one after nine years. Of the nine patients alive and well, five were treated by amputation from six to forty-four months after the first operation. From this it seems probable that when the tumour is confined to bone, adequate resection, either subperiosteally (Baker and Hawksley 1931), or followed by bone grafting (Cagnoli 1944, Hertz 1952), offers as good a prognosis as amputation.

Between the years 1934–42 curettage or local excision was augmented by x-ray or radium therapy in five cases, and invariably there was local recurrence within a few months. This form of treatment was therefore abandoned, but it is worth noting that in our case an inoperable metastasis in the chest wall was considerably reduced by telecobalt irradiation.

SUMMARY

1. The so-called adamantinoma of long bones is a clinico-pathological entity, the pathogenesis of which is still in doubt. The case for its being a synovial sarcoma showing epithelial differentiation is in our view unconvincing.

2. The tumour is slowly growing, and of low grade malignancy. Apparent cure has been effected in a third of the total cases recorded by amputation or resection of the diseased bone.

3. These means, however, have not prevented metastases to the lungs and skeleton in a similar number.

4. A case is presented in which a metastasis appeared in the chest twenty-two years after amputation of the leg. This was sensitive to telecobalt irradiation, and is the first case in which a distant metastasis has been proved microscopically.

We are indebted to Sir Stanford Cade for permission to record this case. We wish to thank Dr Peter Kerley for the radiograph and the West London Hospital for their kindness in making the original notes available.

REFERENCES

ANDERSON, C. E., and SAUNDERS, J. B. de C. M. (1942): Primary Adamantinoma of the Ulna. Surgery, Gynecology and Obstetrics, **75,** 351.

BAKER, A. H., and HAWKSLEY, L. M. (1931): A Case of Primary Adamantinoma of the Tibia. British Journal of Surgery, **18,** 415.

BAKER, P. L., DOCKERTY, M. B., and COVENTRY, M. B. (1954): Adamantinoma (So-called) of the Long Bones. Journal of Bone and Joint Surgery, **36–A,** 704.

BELL, A. L. (1942): A Case of Adamantinoma of the Femur. British Journal of Surgery, **30,** 81.

BENNETT, G. A. (1947): Malignant Neoplasms Originating in Synovial Tissues (Synoviomata). Journal of Bone and Joint Surgery, **29,** 259.

BERGER, L. (1938): Synovial Sarcomas in Serous Bursae and Tendon Sheaths. American Journal of Cancer, **34,** 501.

BOYD, W. (1955): Pathology for the Surgeon. Seventh edition, p. 578. Philadelphia and London: W. B. Saunders Company.

CAGNOLI, H. (1944): Adamantinoma de la Tibia. Archivos Uruguayos de Medicina, Cirugía y Especialidades, **24,** 237.

CASINI, A. (1935): Epitelioma malpighiano su antico focolaio osteomielitico della tibia (cosi detto adamantinoma di Fischer?). Policlinico, Sezione Chirurgica, **42,** 338.

FISCHER, B. (1913): Über ein primäres Adamantinom der Tibia. Frankfurter Zeitschrift für Pathologie, **12,** 422.

HERTZ, J. (1952): Adamantinoma of the Long Bones. Acta Orthopaedica Scandinavica, **22,** 64.

HICKS, J. D. (1954): Synovial Sarcoma of the Tibia. Journal of Pathology and Bacteriology, **67,** 151.

KING, E. S. J. (1933): Post-traumatic Epidermoid Cysts of Hands and Fingers. British Journal of Surgery, **21,** 29.
KING, E. S. J. (1952): Tissue Differentiation in Malignant Synovial Tumours. Journal of Bone and Joint Surgery, **34–B,** 97.
LAUCHE, A. (1947): Zur Kenntnis von Pathologie und Klinik der Geschwülste mit synovialmembran-artigem Bau (Synovialome oder synoviale Endothelio-Fibrome und Sarkome). Frankfurter Zeitschrift für Pathologie, **59,** 2.
LEDERER, H., and SINCLAIR, A. J. (1954): Malignant Synovioma Simulating " Adamantinoma of the Tibia." Journal of Pathology and Bacteriology, **67,** 163.
MAIER, C. (1900): Ein primäres myelogenes Plattenepithelcarcinom der Ulna. Bruns' Beiträge zur klinischen Chirurgie, **26,** 553.
MANGALIK, V. S., and MEHROTRA, R. M. L. (1952): Adamantinoma of the Tibia. Report of a Case. British Journal of Surgery, **39,** 429.
NOVÉ-JOSSERAND, G., and TAVERNIER, L. (1927): Tumeurs malignes des os, p. 164. Paris: Doin.
PÉROCHON and VELUET (1928): À propos du diagnostic radiologique d'une tumeur du tibia. Journal de Radiologie et d'Électrologie, **12,** 178.
RYRIE, B. J. (1932): Adamantinoma of the Tibia. Aetiology and Pathogenesis. British Medical Journal, **ii,** 1,000.
SIMON, W. V. (1923): Die Knochensarkome. Ergebnisse der Chirurgie und Orthopädie, **16,** 199.
TILLOTSON, J. F., MCDONALD, J. R., and JANES, J. M. (1951): Synovial Sarcomata. Journal of Bone and Joint Surgery, **33–A,** 459.
VANEK, J. (1951): Carcinoma Sarcomatodes Tibiae (Adamantinoma Tibiae). Rozhledy v Chirurgii, **30,** 499.
WRIGHT, C. J. E. (1952): Malignant Synovioma. Journal of Pathology and Bacteriology, **64,** 585.

UNREDUCED TRAUMATIC DISLOCATION OF THE HIP

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From the Arabian American Oil Company Hospital

This hospital is situated near the Persian Gulf in Saudi Arabia, where it gives medical service to thousands of employees from about twenty-eight nations, and to native non-employees.

Once in a while a case is brought from the heart of the desert, well taken care of by nature but badly neglected where modern medical service is concerned.

CASE REPORT

A twenty-four years old Bedouin fell from a height of about twenty feet and sustained a serious injury to his right hip, after which he was bedridden for a month and then gradually began walking again. When he reported for the first time to the hospital a year after the injury he walked with an obvious limp due to pronounced apparent lengthening of the right leg. There was severe tilting of the pelvis to the right, with compensatory lateral curvature,

FIG. 1
The patient before operation.

and moderate atrophy of the right thigh and leg muscles (Fig. 1). He used a primitive cane for support when walking. Nature had taken good care of him: movements at the right hip were only slightly limited except for abduction; as the apparent lengthening was due to severe abduction, this movement could not be carried any further. There was no sign of any nerve involvement. A radiograph showed an unreduced inferior dislocation of the right hip, with the head of the femur in the region of the obturator foramen forming a new false acetabulum

from calcified fibrous tissue (Fig. 2). The greater trochanter nearly touched the original acetabulum, the pelvis was severely tilted, the femur abducted and the spine curved laterally. Movements at the hip were only slightly painful, but the man was about to get married; so he was advised by the elderly men of the tribe to seek correction of the deformity in the Company's

FIG. 2
Radiograph before operation.

FIG. 3
Radiograph after operation.

hospital. So he did, and after a three days' journey on camel back he reached the nearest trans-Arabian pipe-line station, from where he came by air over 500 miles.

Operation—At operation the right hip region was exposed through a modified Smith-Petersen incision. The rectus femoris muscle was detached from its double origin and the iliopsoas

from its insertion; without these two steps it was impossible to expose the acetabulum and the displaced femoral head behind the pectineus and origin of the adductor longus muscles. The acetabulum was cleaned thoroughly by excising all fibrous tissue and adherent capsule, sparing most of the posterior part of the capsule. The false joint was exposed with some difficulty by retracting the pectineus muscle and the femoral vessels and nerve medially. The fibrous tissue forming a false capsule was excised to expose the head of the femur and to facilitate its displacement from the well formed, hard, calcified false socket.

The femoral head was displaced with some difficulty by lateral rotation, adduction, flexion and traction. The shortening of the muscles made reduction difficult, but it was achieved by the same manoeuvres of adduction, flexion and traction but this time with medial rotation instead of lateral. Flexion at the hip had to be maintained at 40 degrees to allow the

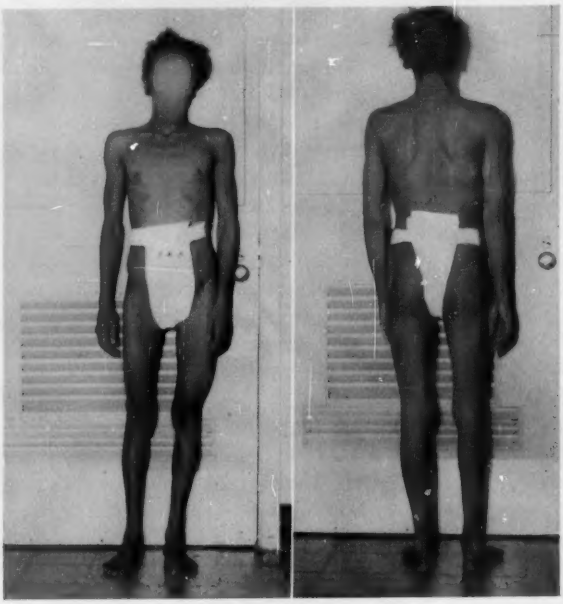

FIG. 4
The patient after operation.

reconstruction of the detached muscles and closure of the wound. After closure extension of the hip was impossible; so the limb was supported on a Thomas's splint with a Pearson flexed knee attachment keeping the hip semi-flexed. Continuous weight traction was applied and the hip was extended by 5 degrees a day until full extension was reached on the ninth day. Thereafter intensive rehabilitation was continued. The patient walked with crutches after two weeks but by the end of the third week he needed no support at all and insisted on going home (Figs. 3 and 4).

REFERENCES

CAMPBELL'S OPERATIVE ORTHOPAEDICS (1949): Edited by J. S. Speed and H. Smith. Second edition. London: Henry Kimpton.

LAST, R. J. (1954): Anatomy: Regional and Applied. London: J. & A. Churchill Ltd.

TRUETA, J., and HARRISON, M. H. M. (1953): The Normal Vascular Anatomy of the Femoral Head in Adult Man. Journal of Bone and Joint Surgery, **35–B**, 442.

WATSON-JONES, R. (1955): Fractures and Joint Injuries. Fourth edition. Edinburgh and London: E. & S. Livingstone Ltd.

THE PREHENSILE MOVEMENTS OF THE HUMAN HAND

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The function of the human hand in terms of the discrete movement of the joints and the action of individual muscles is well enough understood. Little is known, however, of the movements of the hand as a whole. It is possible to talk loosely of closing, opening or cupping the hand; of selected postures such as the pinch or hook or of prehensile functions such as grasping and gripping. These terms are not only unscientific but have little or no universal connotation.

The need for a system of disability evaluation of the hand in connection with industrial and insurance work has resulted in the development of several methods of analysing the function of the hand as a unit. Griffiths (1943 and personal communications) has for many years divided the functions of the hand into cylinder grip, ball grip, ring grip, pincer grip and pliers grip. These terms, although expressive and useful are somewhat selective in that they represent a series of functional end-results rather than a fundamental analysis of the potential of the hand as a whole. The units of function devised by Slocum and Pratt (1946)—namely, grasp, pinch and hook—are not clearly defined nor are they comprehensive, for no allowance appears to be made, for instance, for the numerous functions of the hand in which the thumb is not in opposition. The classification proposed by McBride (1942) divides the functions of the hand into three types: grasping by the hand as a whole, grasping between the thumb and fingers and grasping by the combined use of the palm and the digits. These three types of movement are somewhat arbitrarily conceived and do not appear to have any particular functional or anatomical basis.

A terminology, if it is to be effective and generally acceptable, must develop out of a fundamental approach to the problem of the function of the hand as a whole and it seems that little has been done in this respect. The purpose of this paper is to present a method of classifying prehensile movements based on such an approach. The two discrete patterns of movement that have emerged through this study are analysed from both the anatomical and functional points of view and are termed *precision grip* and *power grip*.

PREHENSILE AND NON-PREHENSILE MOVEMENTS

The movements of the hand can be divided into two main groups: 1) *Prehensile movements*—or movements in which an object is seized and held partly or wholly within the compass of the hand; and 2) *non-prehensile movements*—or movements in which no grasping or seizing is involved but by which objects can be manipulated by pushing or lifting motions of the hand as a whole or of the digits individually. The present paper is concerned solely with prehensile movements.

At first sight it would seem that the prehensile activities of the hand are so extensive and varied that a simple analysis would not be feasible. On closer examination, however, it becomes clear that this diversity is in fact not so much an expression of a multiplicity of movements but of the vast range of purposive actions involving objects of all shapes and sizes that are handled during everyday activity.

A study of the normal hand suggests that there are, in fact, only two distinct patterns of movement in man and that these, either separately or in combination, provide the anatomical basis for all prehensile activities whether skilled or unskilled.

The fundamental requisite of prehension is that the object, whether it is fixed or freely movable, should be held securely. Stability is a pre-requisite for further activity and without

it all refinements of hand function are of little value even in the presence of normal sensory acuity. Stability may be achieved in the normal hand in one of two ways: 1) The object may be held in a clamp formed by the partly flexed fingers and the palm, counter pressure being applied by the thumb lying more or less in the plane of the palm. This is referred to as the *power grip** (Fig. 1). 2) The object may be pinched between the flexor aspects of the fingers and the opposing thumb. This is called the *precision grip** (Fig. 2).

It is clearly important to establish that these two operations are distinct both in the anatomical and in the functional sense.

The very nature of this study makes it difficult to support assertions with any form of proof other than that provided by the photographs and by the confirmatory evidence of the reader's own hands.

FIG. 1
A power grip posture.

FIG. 2
A precision grip posture.

FACTORS INFLUENCING THE POSTURE OF THE HAND DURING FUNCTION

The shape of the object—The terms "ball grip" and "cylinder grip" have been used by Griffiths (1943) to designate postures similar to, though not identical with, the fundamental postures described above. Griffiths's terms have a considerable graphic value but are unsatisfactory in that they suggest that the posture of the hand is conditioned, essentially, by the shape of the object held. In fact, a ball or a cylinder may be held in either one of these two fundamental postures with equal security. For example, a short slender cylinder of wood may be gripped as securely between the tips of the opposed digits as between the flexed fingers and the palm. Which of the two postures is adopted depends solely upon the purpose to which the wooden rod is to be put. A wooden rod, as such, has multiple potentialities and can be used as a tool in a variety of ways. If, for example, it is to be used for writing, it will usually be held between the tip of the thumb and the opposed digits (Fig. 3); but if, on the other hand, it is employed for the purpose of hammering a nail, it is most likely

* The terms precision grip and power grip are used in a dynamic as well as a static sense in the same way that flexion and extension are employed to describe both the posture and the movement.

to be held clamped between the flexed fingers and the palm and reinforced by the thumb (Fig. 4). In other words the shape of the rod itself, in this example, has no bearing on the posture adopted by the hand. Another illustration of the same point is provided by the activities shown in Figures 5 and 6. In Figure 5 the right hand, which is in the process of unscrewing the tightly screwed-up lid of a jar, is in a power grip posture. In Figure 6 the

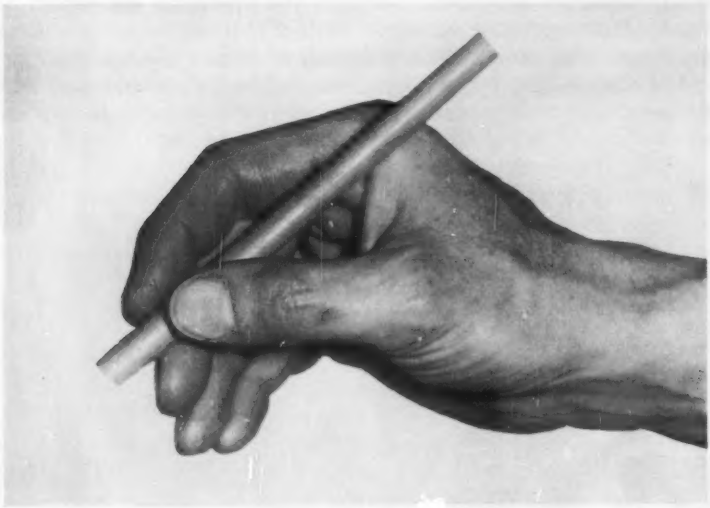

FIG. 3
Wooden rod held in a writing position.

FIG. 4
Wooden rod held in a hammering position.

lid of the jar is loose and the hand has adopted a precision grip posture to facilitate the terminal stages of unscrewing as well as the final removal of the lid. The lid in becoming loose on its thread has undergone a change in physical relationship to the jar but there has been no change in its outward physical form. This change in relationship is reflected in the adoption by the hand of a form of prehension that is best adapted to the exercise of precision.

It may with truth be pointed out that certain tools with cylindrical handles are habitually gripped between the flexed fingers and palm in a power grip. Rather than refuting the present

FIG. 5
As the lid is started the right hand is in a power grip posture.

FIG. 6
As the lid becomes loose the right hand assumes a precision grip posture.

hypothesis that the shape of the handle has no influence on the type of grip employed, this apparent anomaly merely indicates that, as a result of past experience, hand tools designed for a particular operation are manufactured in a form to suit the hand during that activity.

The size of the object—In the intermediate size ranges either the precision grip posture or the power grip posture provides equally effective stabilisation. In the larger sizes, however, the posture of election is that which provides the greatest span of the hand compatible with stability. Thus a sphere of large diameter is supported preferably by both hands, but if one hand only is available it is held in a precision grip between the tips of the widely spread finger and thumb. At the opposite extreme, very small objects tend to be held between the pulp surfaces of the index finger and thumb—also a precision grip posture. Stability in this latter instance is more a matter of sensory acuity than mechanical support. Thus, although size contributes to the choice of grip at the extremes of the size range, it is clear that this factor has no general application.

Miscellaneous factors—Certain other physical factors such as the weight, the texture, the temperature and the wetness or dryness of the object may, under certain conditions, influence the type of grip employed; other factors such as fear, distaste and hunger may also condition the grip in certain circumstances.

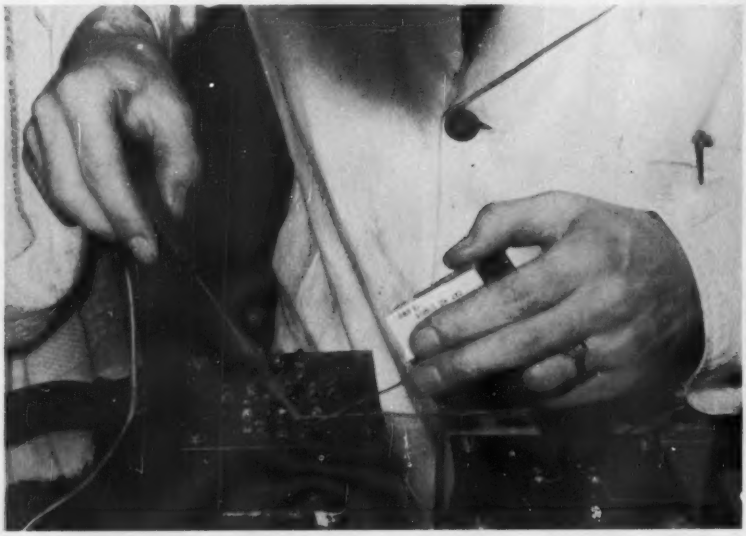

FIG. 7

The right hand is in a precision grip posture, the left in a power grip posture.

The influence of intended activity—During the performance of a purposive prehensile action the posture of the hand bears a constant relationship to the nature of that activity. If prehensile activities are to be regarded as the application of a system of forces in a given direction then the nature of prehensile activity can be resolved into two concepts—that of *precision* and that of *power*. Although in most prehensile activities either precision or power is the dominant characteristic, the two concepts are not mutually exclusive. In some manual operations the application of power is of primary importance and the need for precision only secondary (Fig. 5); in others, need for precision is pre-eminent while that for power is subordinate (Fig. 6). It appears that the predominance of either precision or power requirements in any given activity determines the posture of the hand.

While it is fully recognised that the physical form of the object may in certain conditions influence the type of prehension employed it is clear that it is the nature of the intended activity that finally influences the pattern of the grip. Thus it becomes possible to divide

prehensile movements of the hand into two main types by determining whether the dominant characteristic of the movement is one of precision or of power. It seems convenient and appropriate, therefore, to refer to the operations of precision grip and power grip. These terms are simple and at the same time have the advantage of reflecting the functional affinities of the grip in a specific manner. It is a matter of common observation that if prehensile movement is arrested at any moment of activity, the hand inevitably exhibits some phase of either precision grip or power grip (Fig. 7), and it appears that these two, therefore, embody the whole range of prehensile activity of the human hand.

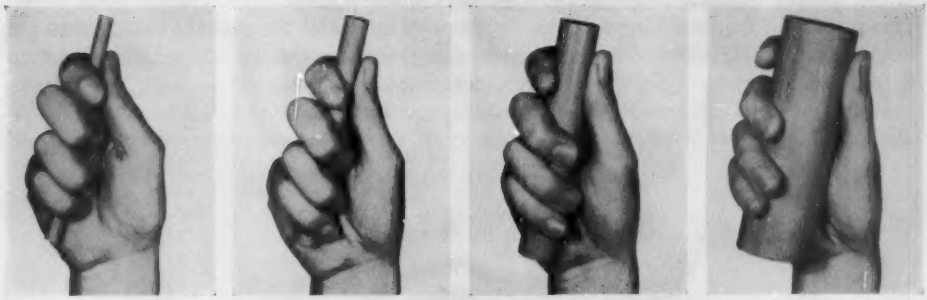

FIG. 8
An arbitrarily chosen series of postures illustrating some of the phases of the power grip complex.

FIG. 9
An arbitrarily chosen series of postures illustrating some of the phases of the precision grip complex.

ANATOMICAL FEATURES OF POWER AND PRECISION GRIP

As pointed out above the terms power and precision grip have a dynamic as well as a static connotation. In their dynamic sense they are used to refer to movements of the hand as a whole in the same way, for example, as flexion is used to refer to the movement at a single joint. Whereas the phases of flexion are capable of being represented mathematically as degrees of movement, no such quantitative measure can be applied to power and precision grip, which, though simple enough in concept, are, in the final analysis, extremely complicated biomechanical operations involving movements in all the joints of the hand at the same time. Thus, while it is possible to recognise the almost infinite number of phases within the grip complexes, it is impossible to treat these phases biometrically. A selection of some of the phases of each grip are illustrated in Figures 8 and 9.

The essential anatomical features of the two grips become evident when the thumb and fingers are considered separately.

The posture of the thumb—The position of the thumb differs fundamentally in the two grips (Figs. 8 and 9). In the power grip it is adducted* at both metacarpo-phalangeal and carpo-metacarpal joints, while in the precision grip it is abducted at both these joints. During activity the thumb is always in one or other position, for in the mid-position or position of rest (Ellis 1878) the carpo-metacarpal joint is unstable by virtue of its lax ligaments and incongruous joint surfaces. Only in abduction and adduction does the thumb fulfil the basic need for stability (Napier 1955). In precision grip the thumb forms one jaw of a clamp, the opposing jaw being formed by part or whole of the flexor surfaces of the fingers. In this grip the thumb is not only abducted and medially rotated at the carpo-metacarpal but also at the metacarpo-phalangeal joint (Napier 1952), and is thus in opposition† to the remaining digits. This posture of the thumb ensures that the sensory surface of the digits is employed to the fullest advantage, thus providing the greatest opportunities for delicate adjustments of posture in response to the activity of the skin receptors.

FIG. 10
A power grip posture in which the element of precision plays a large part. (The subject of this photograph is a fencing master.)

It has already been pointed out that the concepts of power and precision have to be considered in both the power grip and the precision grip, but that it is the predominance of one or the other that is responsible for the anatomical characteristics of the grip. The element of precision in the power grip complex is reflected in the posture of the thumb. When there is little or no demand for precision the thumb becomes wrapped over the dorsum of the middle phalanges of the digits, where it acts purely as a reinforcing mechanism. When an element of precision is required in what is predominantly a power grip the thumb becomes adducted so that by means of small adjustments of posture it can control the direction in which the force is being applied (Fig. 10).

* In the crudest phases of the power grip—the coal-hammer grip—the thumb is fully abducted. This is a special case and will be discussed below.

† The term opposition of the thumb is defined as a movement which results in the pulp surface of the thumb becoming diametrically opposed to the pulp surface of one or all of the remaining digits for the purposes of prehension (Napier 1955).

The main function of the hand in power grip is to provide a means of resisting any system of forces that may be applied to the object within its grasp. These forces can be resolved into three forces of translation and three couples of rotation as illustrated in Figure 11. It can be seen that when the thumb is wrapped over the dorsum of the digits it can best resist certain of these forces and couples by providing a powerful buttress on the lateral side. The effect of this buttress is lost, however, when the thumb becomes adducted and aligned in the long axis of the cylinder, with the result that some of the power of the grip is sacrificed in the interests of precision.

In general, therefore, the greater the force required of the grip as a whole, the more the thumb is required to act as a reinforcing and buttressing mechanism and the less it is able to contribute to precision. This is well illustrated in a functional manner by the posture of the hand gripping a series of hammers of different types and sizes (Figs. 12 to 15). These photographs show postures that were adopted without any prior instruction by a craftsman well versed in the use of an appropriate hammer for a specific operation. It can be seen that the thumb becomes increasingly abducted, flexed and medially rotated as the hammer becomes

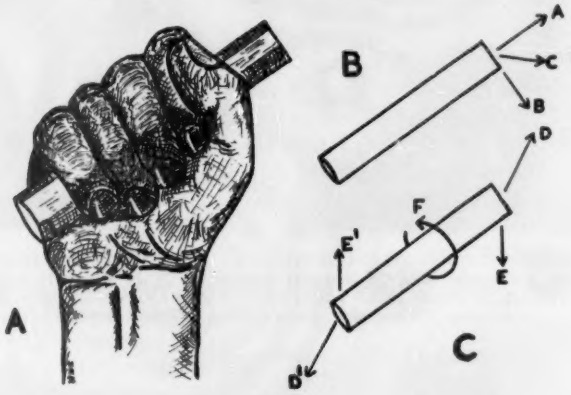

FIG. 11

The thumb forms a powerful buttress to the lateral side of the hand. B shows the forces of translation capable of acting on a rod held as in A. C shows the couples of rotation capable of acting on a rod held as in A.

longer and heavier. Eventually a stage is reached (Fig. 15) where the thumb, no longer in contact with the hammer handle, has ceased to contribute any element of precision to the operation, being wholly occupied in reinforcing the clamping action of the digits. This latter grip, which is termed the coal-hammer grip (Fig. 16) is the crudest form of prehensile function and constitutes one extreme, as it were, of the power grip range. Such precision as accompanies its use is achieved by movements of the rest of the upper limb and the body as a whole. The bunched fist (Fig. 17) is merely another example of the coal-hammer grip, applied, as it were, to an empty hand and constituting in itself a weapon.

The posture of the fingers—The relative positions of the fingers in power grip and precision grip differ considerably, but the postures in each are well suited to the function they have to perform. During power grip the fingers are more or less flexed, forming one jaw of the clamp, the palm forming the other jaw. The degree of flexion of the fingers and the area of the palm involved vary according to the dimensions of the object held (Fig. 8). The fingers are flexed, laterally rotated and inclined towards the ulnar side of the hand; hypothenar elevation forms an important part of the grip by providing a muscular cushion on the ulnar side of the hand to oppose the thenar eminence.

FIG. 12

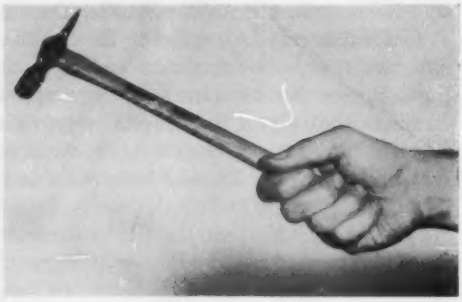

FIG. 13

FIG. 14

FIG. 15

A series of hammer grips demonstrating the changing relationship of the thumb to the shaft of the hammer as the size of the tool increases. Figure 12—A pin hammer. Figure 13—A Warrington hammer. Figure 14—A cross-pein hammer. Figure 15—A ball-pein hammer.

FIG. 16

FIG. 17

Figure 16—The coal-hammer grip. Figure 17—The bunched fist. Note that the ulnar deviation characteristic of a power grip is apparent in both these figures.

During the precision grip the fingers are flexed and abducted at the metacarpo-phalangeal joints, which serves to increase the span of the hand and to produce a degree of axial rotation of the digits. The extent to which the fingers are flexed and axially rotated depends largely on the size and shape of the object that they are to contain (Fig. 9). As the size of the object diminishes the need for precise handling becomes proportionately greater and, in order to facilitate this, there is a shift of the axis of the precision grip towards the thumb and index finger, digits which are best adapted to exercise fine control.

FIG. 18
A combined grip.

The posture of the hand on the forearm—The relationship of the hand to the forearm differs strikingly in the two grips (Figs. 8 and 9). In the power grip the hand is deviated towards the ulnar side and the wrist is held in the neutral position between full extension and full flexion; in this position the long axis of the thumb coincides with that of the forearm. In the precision grip the hand is held midway between radial and ulnar deviation and the wrist is quite markedly dorsiflexed. In passing from the power grip to the precision grip position, the thumb moves from a position of adduction to one of abduction and is thus no longer in the line of the long axis of the forearm. Realignment of the thumb in relation to the forearm is achieved by correcting the ulnar deviation of the hand and further dorsiflexing the wrist.

Combined grips — Although, as a general rule, it is true to say that if the motion of the hand be arrested at any moment of activity it will inevitably show some phase of power grip or precision grip, there are certain activities of the hand in which the two grips are combined at one and the same time. The precision grip element is usually the dominant one and the inner three digits, which are redundant when a small object is handled, are free to be utilised in a purely supplementary role (Fig. 18). In terms of everyday activity this composite grip is employed when, for example, a knot is tied in a piece of cord (Fig. 19).

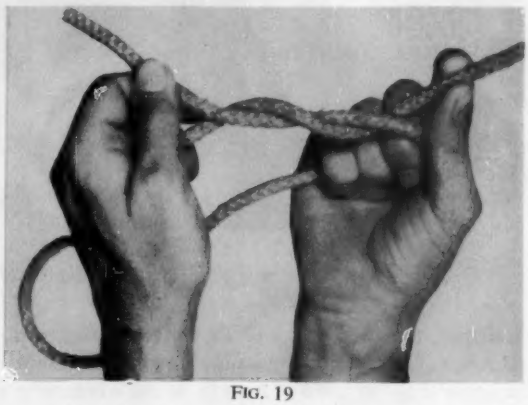

FIG. 19

A combined grip. Note that the index finger and thumb are in a precision grip posture while the remaining digits are in a power grip posture in both figures.

The hook grip—Some mention must be made of a type of prehensile grip in which the thumb plays little or no part. This is the so-called hook grip which requires relatively little muscular effort to maintain and is employed under conditions when precision requirements are minimal and when power needs to be exerted continuously for long periods, as for example when shopping baskets or suitcases are carried (Fig. 20). The hook grip is

also used when for any reason it is impossible to obtain more than a finger-tip hold, as, for example, during the opening or closing of one half of a sash window. This latter function is to all intents and purposes, however, non-prehensile. In the normal individual this grip has limited potentialities and is therefore only rarely used, but in the disabled individual with paralysis of the intrinsic muscles of the hand, it is virtually the only form of prehension possible.

CONCLUSION

It is perhaps rather surprising to find that the prehensile movements of the human hand may be resolved into two such simple conceptions as precision grip and power grip. This feeling of surprise would seem to stem from a proneness to confuse movements with purposive

FIG. 20
The hook grip. Note the passive role of the thumb in this grip.

activities, the multiplicity of the latter tending to obscure the fundamental simplicity of the former. There is, too, possibly an understandable lack of objectivity which leads one to suppose that the hand of man is, in the words of a nineteenth century authority, " the most perfect and complete mechanical organ that nature has yet produced." While the perfection and completeness of its accomplishments are not in doubt, the implicit idea that such an organ is a specialisation of man is open to criticism. In many respects the human hand is a remarkably primitive structure, the pitfalls of extreme specialisation shown, for example, by the gibbon, the potto and the baboon having been avoided in its phylogenetic history. In its pentadactyl form, the relative length of its digits, the arrangement of its musculature and in the generalised nature of its movements, man's hand shows an ancient simplicity of structure and function. The human hand is little better endowed, in a purely material sense, than that

of any generalised primate in whom the thumb is present and specialised. In this connection Wood Jones (1941) wrote: "We shall look in vain if we seek for movements that man can do and a monkey cannot, but we shall find much if we seek for purposive actions that man can do and a monkey cannot." The heart of the matter lies in the term "purposive actions," for it is in the elaboration of the central nervous system and not in the specialisation of the hand that we find the basis of human skill.

SUMMARY

1. The prehensile movements of the hand as a whole are analysed from both an anatomical and a functional viewpoint.
2. It is shown that movements of the hand consist of two basic patterns of movements which are termed precision grip and power grip.
3. In precision grip the object is pinched between the flexor aspects of the fingers and that of the opposing thumb.
4. In power grip the object is held as in a clamp between the flexed fingers and the palm, counter pressure being applied by the thumb lying more or less in the plane of the palm.
5. These two patterns appear to cover the whole range of prehensile activity of the human hand.

My thanks are due to the Medical Research Council who provided a grant for this work; to numerous colleagues who have contributed both ideas and criticisms to this study; to D. A. Fenton, G. Fraser and L. Grayson whose hands are used as models; to A. L. Wooding of the Photographic Department of St Thomas's Hospital Medical School and to Mrs J. M. Thomas of the Photographic Unit of this medical school for their excellent photographs.

REFERENCES

ELLIS, T. S. (1878): The Position of Rest in Fatigue and in Pain. British Medical Journal, **i**, 84.
ELLIS, T. S. (1889): The Human Foot. London: J. & A. Churchill.
GRIFFITHS, H. E. (1943): Treatment of the Injured Workman. Lancet, **i**, 729.
GRIFFITHS, H. E.: Personal communications.
JONES, F. Wood (1941): The Principles of Anatomy as Seen in the Hand. Second edition. London: Baillière, Tindall & Cox.
MCBRIDE, E. D. (1942): Disability Evaluation. Third edition. Philadelphia, London, Montreal: J. B. Lippincott Company.
NAPIER, J. R. (1952): The Attachments and Function of the Abductor Pollicis Brevis. Journal of Anatomy, **86**, 335.
NAPIER, J. R. (1955): Form and Function of the Carpo-metacarpal Joint of the Thumb. Journal of Anatomy, **89**, 362.
SLOCUM, D. B., and PRATT, D. R. (1946): Disability Evaluation for the Hand. Journal of Bone and Joint Surgery, **28**, 491.

HISTOLOGICAL CHANGES IN EXPERIMENTALLY DISPLACED UPPER FEMORAL EPIPHYSES IN RABBITS

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Few observations have been made on the histological changes associated with slipped femoral epiphysis. Those that are available are confusing, if not actually misleading, in that they have been made on material removed at operation some considerable time after the event, and thus show only the late stages of repair (Lacroix and Verbrugge 1951, Sutro 1935). So far as we are aware no observations are available on the early stages of the disease, particularly the prodromal change which allows the displacement to occur.

Since opportunities to secure such material clinically are rare indeed, recourse to experimental methods is desirable. A method has been devised for detaching the upper femoral epiphysis in growing rabbits. While it is admitted that this technique does not parallel the common clinical situation of insidious displacement, it does allow study of the early phases of repair after acute displacement, and is of special value in assessing the various surgical procedures used in treatment of this condition.

MATERIAL AND METHODS

Five to six weeks old male rabbits were used. One hip joint was exposed through a postero-lateral approach and the femur was dislocated from the acetabulum. The periphery of the epiphysial plate could be seen as a rather sinuous blue line. The perichondrium overlying this was incised with a scalpel. This allowed the introduction of a small periosteal elevator, and gentle pressure on this allowed the capital epiphysis to be completely detached. The epiphysis was then reattached to the femoral neck and held by means of a fine Kirschner wire, introduced from the head into the neck. The animals were killed at weekly intervals up to six weeks. Both the femoral head operated upon and the normal femoral head were removed, fixed in 10 per cent formalin and decalcified in buffered citric acid, sectioned in paraffin and stained with haematoxylin and eosin.

The status of the ligamentum teres was ignored in this experiment, as a preliminary investigation indicated that it had no important role in the blood supply of the femoral head. This finding appears to have been established by the work of other investigators, notably Walmsley (1915), Wolcott (1943) and Tucker (1949).

OBSERVATIONS

The histological changes are best considered separately in each of the three components of the head—the epiphysial cartilage, the bony epiphysis and the articular cartilage.

The epiphysial cartilage—The plane of separation through the epiphysial plate was remarkably constant. In most cases it occurred through the layer of hypertrophied cells on the epiphysial side of the zone of provisional calcification (Figs. 1 and 2). Soon after the separation a prolific outgrowth of primitive tissue arose from the metaphysis. This tissue resembled callus, and contained young osteogenic and chondrogenic cells. The callus grew against the epiphysial fragment of the plate, thus uniting the head to the neck. The cartilage in the epiphysial fragment of the plate underwent a prompt change: the cells lost their orderly columnar arrangement and failed to mature into hypertrophied cells (Fig. 3).

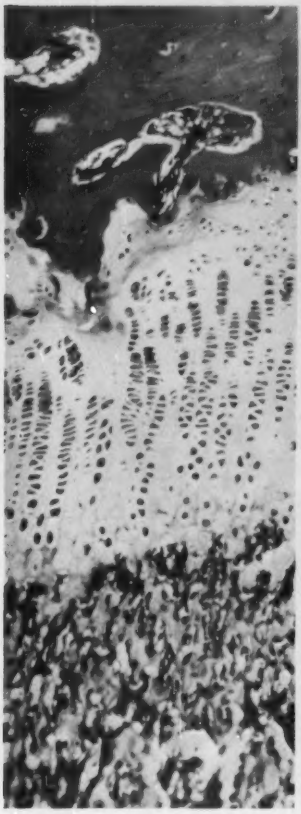

FIG. 1

FIG. 2

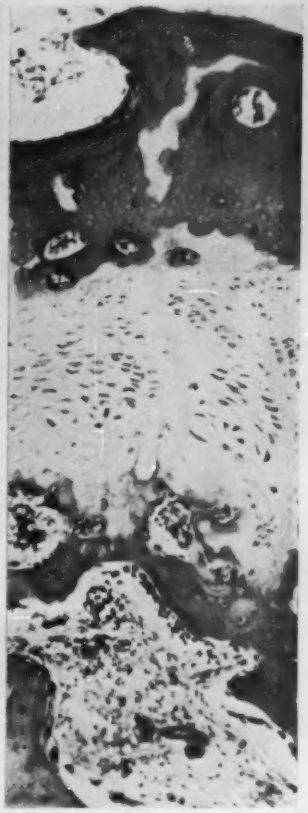

FIG. 3

Figure 1—Normal epiphysial plate. Figure 2—Plane of separation. Figure 3—Three weeks after epiphysial displacement.

The bony epiphysis—Within a few days the epiphysis exhibited all the changes characteristic of dead bone: the lacunae were empty, or contained pyknotic cells, the osteogenic cells

TABLE I

OBSERVATIONS FROM FIRST SERIES OF EXPERIMENTS (EPIPHYSIAL PLATE LEFT INTACT)

Weeks	1	2	3	4	6
Number of animals	9	9	9	8	10
Complete re-ossification	0	1	2	8	10
Partial re-ossification	2	6	6	0	0
No re-ossification	7	2	1	0	0
Marrow replacement	—	—	—	5	5
Deformity	—	—	—	3	4

covering the trabeculae had disappeared, and the marrow had lost its nuclear basophilism and had become eosinophilic (Figs. 4 and 5).

FIG. 4

FIG. 5

Avascular necrosis of head two weeks after epiphysial separation. Figure 4—Control hip. Figure 5—Experimental hip. Note empty lacunae, absence of covering osteogenic cells, and necrotic marrow.

This dead bone was then invaded by the callus arising from the metaphysis and entering the head through gaps in the epiphysial plate. The principal gap was made by the Kirschner wire, but as a rule the trauma of the operation produced other openings, usually at the periphery of the plate, and these also allowed entry of the callus. In the early stages the callus was very vascular, and consisted of primitive cells which resembled young fibroblasts. Later these cells tended to collect on the surfaces of the necrotic trabeculae, where they assumed the appearance of osteoblasts and commenced to lay down new bone matrix on the surface of the old (Figs. 6 and 7). In the final stages the entire head was replaced by new bone and the intertrabecular spaces were filled with seemingly normal bone marrow. This repair process took so long, however, that many of the femoral heads exhibited the collapse and deformity so characteristic of avascular necrosis in man (Fig. 8).

The articular cartilage—In the early stages the articular cartilage showed little change. As avascular necrosis became established, however, the cells tended to clump in nests instead of retaining their regular arrangement, and the intercellular substance became fibrillated. In

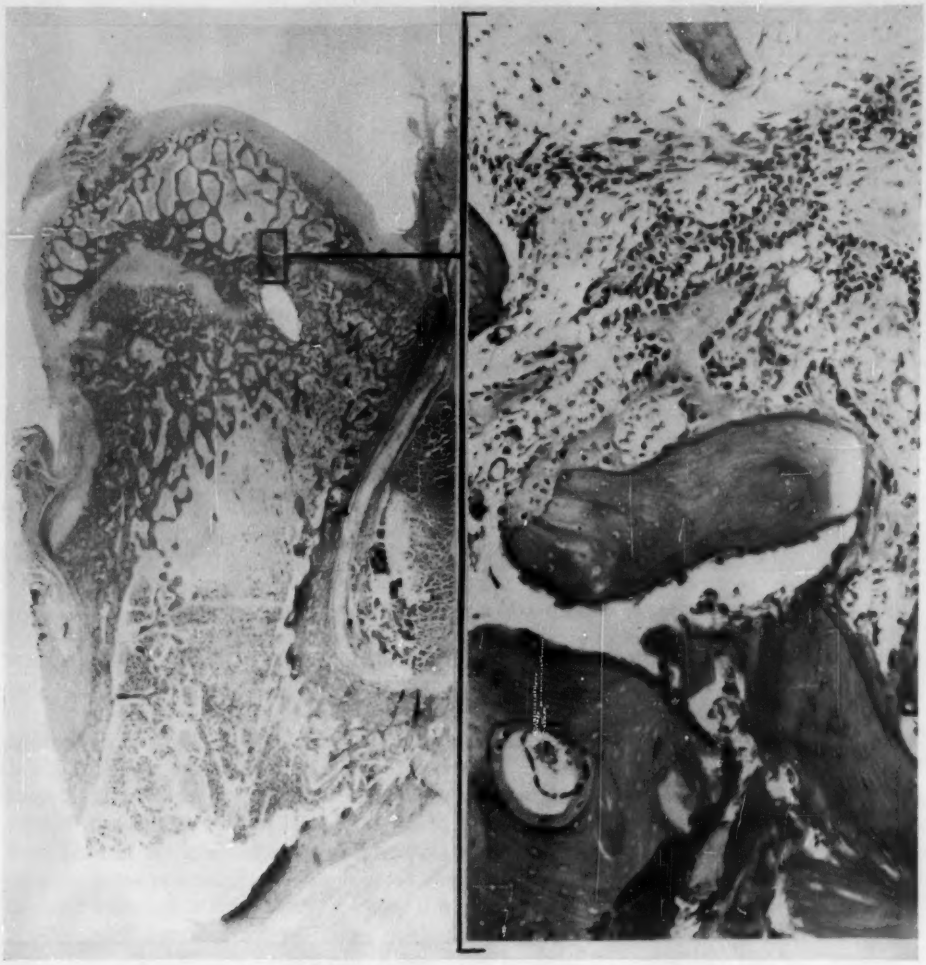

FIG. 6 FIG. 7

Showing ingrowth of new bone from neck through perforation in plate into head. Figure 6—Low power showing site of perforation produced by Kirschner wire. Figure 7—High power of outlined area, showing new bone being laid down on the surface of a dead trabecula.

those heads which had collapsed, the cartilage was often covered by a pannus arising from the synovium of the hip joint.

Rate of revascularisation—The time required for revascularisation was related to the ease with which new bone penetrated the epiphysial plate. In most cases the main portal of entry for the callus was provided by the perforation produced in the plate by the Kirschner wire. Although quantitative measurement of the re-ossification was difficult to determine accurately it was found to be well established at the end of two weeks, and completed after four weeks. These findings are tabulated in Table I.

DISCUSSION

As the upper femoral epiphysis is one of the few in the body entirely covered by articular cartilage the changes seen are not unexpected. Removal of the head automatically disrupts

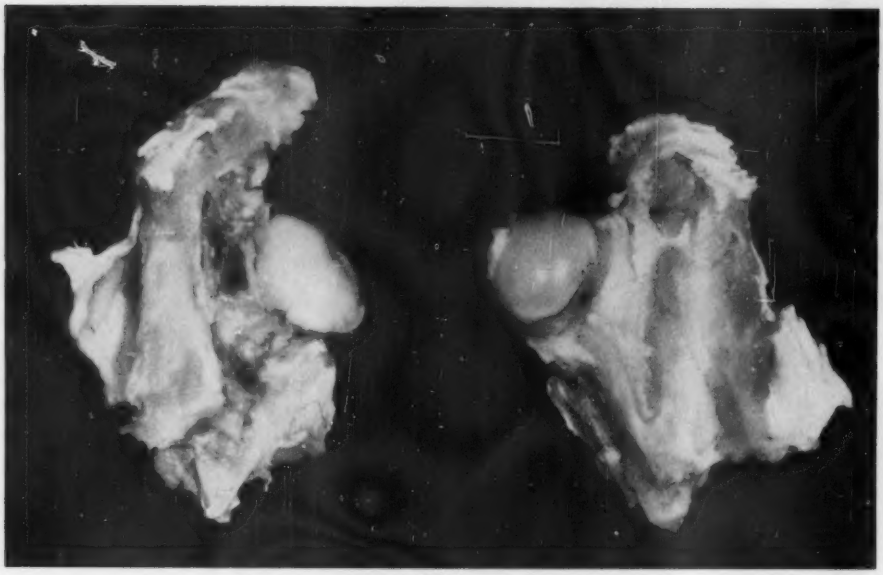

FIG. 8
Avascular collapse of head six weeks after experimental displacement of epiphysis.

its blood supply, causing avascular necrosis. Repair can only occur by the invasion of new bone from the neck, where the blood supply is intact. The most interesting feature is that the separation of the epiphysial cartilage nearly always occurs in such a manner that the bulk of the cartilage remains attached to the epiphysis. The constancy of this plane of cleavage was first noted by Haas (1917). It seems that this is the weakest point in the plate, for at this level only a few collagen fibrils lying in uncalcified cement substance are present to resist shearing stress (Harris 1950). The persistence of the epiphysial plate thus acts as a barrier which must be penetrated by the callus before successful re-ossification of the femoral head can occur. In the experiment, re-ossification was delayed sufficiently long in some cases to allow typical collapse of the head to occur, and it seems probable that if the plate had not been perforated by the Kirschner wire, re-ossification would have taken even longer. In a few cases, however, re-ossification occurred much earlier than the average. This was apparently due to accidental perforation of the plate by instruments at the time of the experimental separation. These extra openings allowed easier entry of the callus, thus allowing more rapid re-ossification of the head. This observation led to the obvious deduction that deliberate removal of the epiphysial plate might allow more rapid re-ossification of the head. To test this idea a second experiment was performed.

MATERIAL AND METHODS

The second experiment resembled the first in every respect except that the epiphysial cartilage was deliberately curetted from the head before the latter was fixed to the femoral neck.

OBSERVATIONS

Exactly the same sequence of events occurred as in the first experiment, but the time required for these changes was sharply reduced. Vascular osteogenic tissue had invaded half the femoral heads by the end of one week, and between the second and third weeks most of the heads were completely re-ossified. Moreover, removal of the epiphysial plate allowed re-ossification to advance in a uniform manner, instead of in the patchy distribution seen in the first

experiment. It is also significant that the marrow was replaced at an earlier date, and that after six weeks there was only one deformed head in contrast to four seen in the first experiment. These findings are tabulated in Table II, and Figure 9 is a graph comparing the time required for re-ossification in each of the two experiments.

TABLE II

OBSERVATIONS FROM SECOND SERIES OF EXPERIMENTS (EPIPHYSIAL PLATE REMOVED)

Weeks	1	2	3	4	6
Number of animals	8	9	8	9	9
Complete re-ossification	0	6	6	8	9
Partial re-ossification	4	1	2	1	—
No re-ossification	4	2	0	0	—
Marrow replacement	—	—	—	7	8
Deformity	—	—	—	0	1

DISCUSSION (concluded)

These observations appear to confirm that the epiphysial plate does act as a barrier to re-ossification of the head, and that its removal appreciably reduces the time required for this process. The findings have an important clinical application in the choice of operative technique in cases of slipped epiphysis requiring open reduction. It has been held that an open reduction through the epiphysial plate would be certain to damage any remaining blood

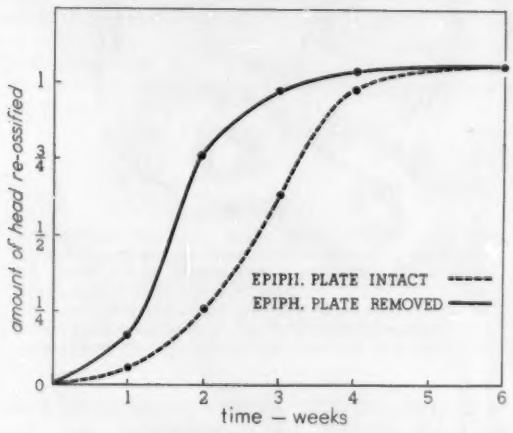

FIG. 9

Graph comparing the rates of re-ossification of the head in the two experiments.

supply to the femoral head and bring about avascular necrosis. For this reason Green (1945) advocated a wedge osteotomy of the neck in order that the deformity could be corrected without damage to the blood supply. But it is common experience that cuneiform osteotomy is followed by avascular necrosis in a high percentage of cases. Paradoxically, Klein and his co-workers (1953), who have done open reduction through the plate in all of their cases,

so far have observed only two examples of avascular necrosis in eighty-two cases of slipped epiphysis (Joplin 1955). It seems to us that either of these procedures could damage the blood supply to the femoral head. The difference in results is related to the site of the vascular damage. The cuneiform osteotomy is so located that it leaves part of the metaphysis as well as the entire epiphysial plate undamaged. Re-ossification in this case must first occupy the metaphysial fragment, and then penetrate the more or less intact epiphysial plate before entering the head (Fig. 10). The time required is ample to allow clinically recognisable avascular

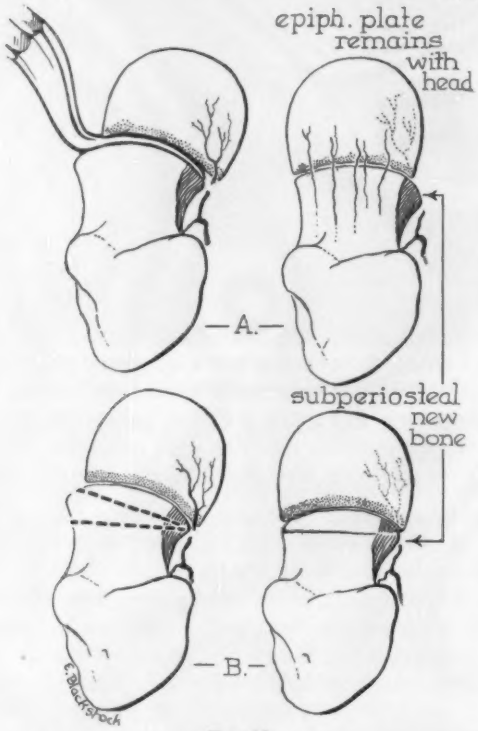

FIG. 10

Drawing to show that either reduction through the epiphysial plate or cuneiform osteotomy of the neck may damage the remaining blood supply to the head. In reduction through the plate (A), the plate is perforated by instruments, thus allowing rapid re-ossification. In cuneiform osteotomy (B) the plate (stippled) remains with the head and acts as a barrier to early re-ossification.

necrosis to occur. In contrast, reduction through the epiphysial plate more than likely is accompanied by unintentional perforation of the epiphysial plate. The gaps so made allow ready entry of callus from the metaphysis, so that even if avascular necrosis does occur it is transitory, and it is healed before it becomes clinically recognisable.

For these reasons we are inclined to advocate, in cases of slipped epiphysis that require open reduction, a procedure which effects replacement through the epiphysial plate, and at the same time deliberate curettage of cartilage from the base of the epiphysis, in order to bring about more rapid re-ossification. It is of interest that this principle has previously been advocated both by Kleinberg and Buchman (1936), and by Compere (1950), but their conclusions have evidently not received the attention they deserve.

SUMMARY

An experimental method is described which permits observations on the early stages of repair after acute displacement of the upper femoral epiphysis. Because the epiphysis is intra-articular, displacement brings about avascular necrosis which is slowly repaired by ingrowth of callus and blood vessels from the stump of the neck. As the bulk of the epiphysial plate remains attached to the epiphysis, it acts as a barrier to successful revascularisation. Deliberate removal of the epiphysial cartilage allows earlier revascularisation. It is suggested that in clinical cases reduction be done through the epiphysial plate rather than through the neck, and that it be accompanied by curettage of the remaining part of the epiphysial plate from the under surface of the head.

The authors wish to thank Professor A. W. Ham in whose department this work was conducted for his invaluable advice and criticism. The work was aided by grants from the R. S. McLaughlin Foundation and the Banting Research Foundation.

REFERENCES

COMPERE, C. L. (1950): Correction of Deformity and Prevention of Aseptic Necrosis in Late Cases of Slipped Femoral Epiphysis. Journal of Bone and Joint Surgery, **32–A,** 351.

GREEN, W. T. (1945): Slipping of the Upper Femoral Epiphysis. Archives of Surgery, **50,** 19.

HAAS, S. L. (1917): The Localization of the Growing Point in the Epiphyseal Cartilage Plate of Bones. American Journal of Orthopedic Surgery, **15,** 563.

HARRIS, W. R. (1950): The Endocrine Basis for Slipping of the Upper Femoral Epiphysis. Journal of Bone and Joint Surgery, **32–B,** 5.

JOPLIN, R. J. (1955): Personal Communication.

KLEIN, A., JOPLIN, R. J., REIDY, J. A., and HANELIN, J. (1953): Slipped Capital Femoral Epiphysis. Springfield, Illinois: Charles C. Thomas.

KLEINBERG, S., and BÜCHMAN, J. (1936): The Operative Versus the Manipulative Treatment of Slipped Epiphysis. Journal of the American Medical Association, **107,** 1,545.

LACROIX, P., and VERBRUGGE, J. (1951): Slipping of the Upper Femoral Epiphysis. Journal of Bone and Joint Surgery, **33–A,** 371.

SUTRO, C. J. (1935): Slipping of the Capital Epiphysis of the Femur in Adolescence. Archives of Surgery, **31,** 345.

TUCKER, F. R. (1949): Arterial Supply to the Femoral Head and its Clinical Importance. Journal of Bone and Joint Surgery, **31–B,** 82.

WALMSLEY, T. (1915): The Epiphysis of the Head of the Femur. Journal of Anatomy and Physiology, **49,** 434.

WOLCOTT, W. E. (1943): The Evolution of the Circulation in the Developing Femoral Head and Neck. Surgery, Gynecology and Obstetrics, **77,** 61.

THE ARTERIAL SUPPLY TO THE ADULT CERVICAL VERTEBRAL BODIES

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The arterial supply to the developing vertebral body has been described by Hanson (1926), Willis (1949) and Ferguson (1950). With the exception of Hanson, who used the bodies of one or two young children, the investigations were made on the thoracic and lumbar vertebrae of foetuses and new-born infants. There were no observations upon the cervical

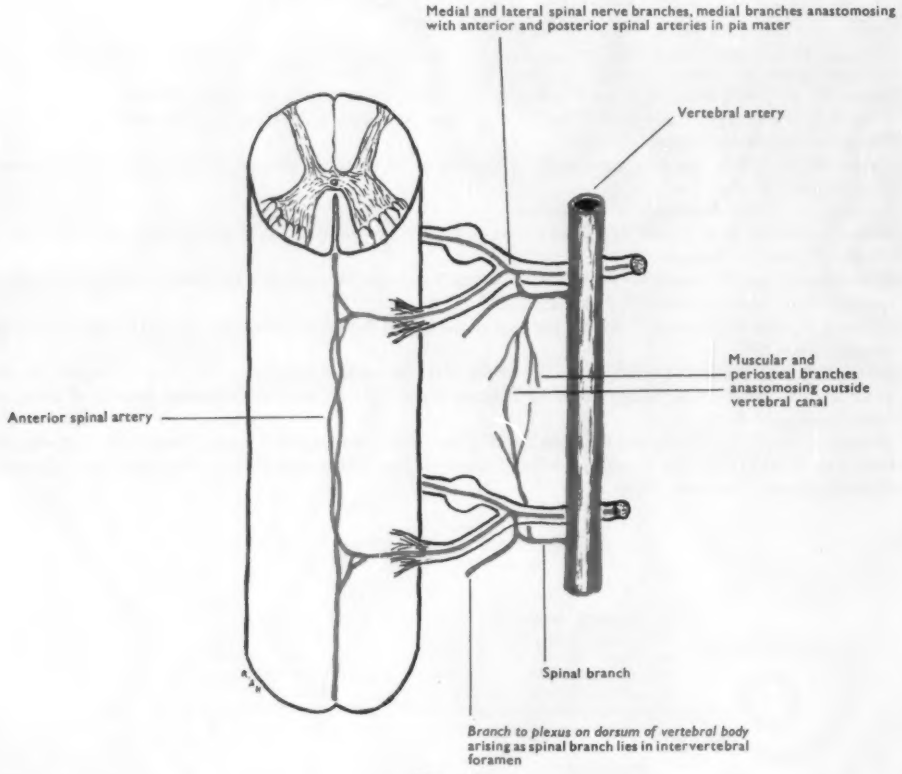
Medial and lateral spinal nerve branches, medial branches anastomosing with anterior and posterior spinal arteries in pia mater
Vertebral artery
Muscular and periosteal branches anastomosing outside vertebral canal
Anterior spinal artery
Spinal branch
Branch to plexus on dorsum of vertebral body arising as spinal branch lies in intervertebral foramen

FIG. 1

Diagram to show segmental artery and its branches.

vertebrae. The observations of these workers were in agreement and may be summarised thus: The main arterial supply to the interior of a developing vertebra enters by the posterior surface. It is derived from an arterial plexus lying deep to the posterior longitudinal ligament extending the length of the spinal canal. The plexus is fed by the thoracic and lumbar segmental branches of the aorta which also supply smaller branches to the antero-lateral surfaces of the bodies.

There is no comparable description in the literature with reference to the fully developed

spine. We therefore investigated this circulation in the cervical spine, using adult vertebrae in place of developing bones. For this purpose we excised the third or fourth to the seventh cervical vertebrae *en bloc* and performed an injection experiment on the fresh specimens.

METHOD

Twelve specimens were investigated, taken from the cadavera of subjects between thirty and sixty years of age. A 50 per cent suspension of Micropaque* in water was used as the injection medium. Each specimen was partly cleared of muscles, and the posterior bone structures (laminae and spinous processes), together with the spinal cord, were removed. It was now necessary to expose the vertebral artery, open it and pass a fine polythene tube into a spinal branch. Micropaque was injected under hand pressure; the flow was observed

FIG. 2

FIG. 3

Figure 2—Arterial anastomosis deep to posterior longitudinal ligament. Decalcified specimen.
Figure 3—Arterial anastomosis deep to posterior longitudinal ligament. Decalcified specimen.

under the dissecting microscope and directed if possible into that branch passing towards the vertebral body. The more successful specimens were radiographed before and after decalcification, and again after sectioning.

ANATOMICAL OBSERVATIONS

The anatomical nature of the specimens made this examination difficult. Our picture of the finer arterial pattern in this region is therefore a composite one, built up from the study of a number of partly successful injections.

In the cervical spine the spinal arterial branches are supplied by the vertebral arteries. Usually single, sometimes paired, these branches enter the spinal canal on the ventral surfaces of the issuing nerve roots, and are larger below than at higher levels. In the intervertebral foramen each spinal vessel divides into three main branches. 1) One branch continues medially

* Supplied by Damancy & Co. Ltd.

along the nerve roots to anastomose with the anterior and posterior spinal arteries supplying the spinal cord, and also gives off a recurrent branch passing laterally along the nerve. 2) One or more small vessels supply the laminae and related soft structures (ligamenta flava and muscles). 3) A branch to the dorsal arterial plexus supplies the vertebral body.

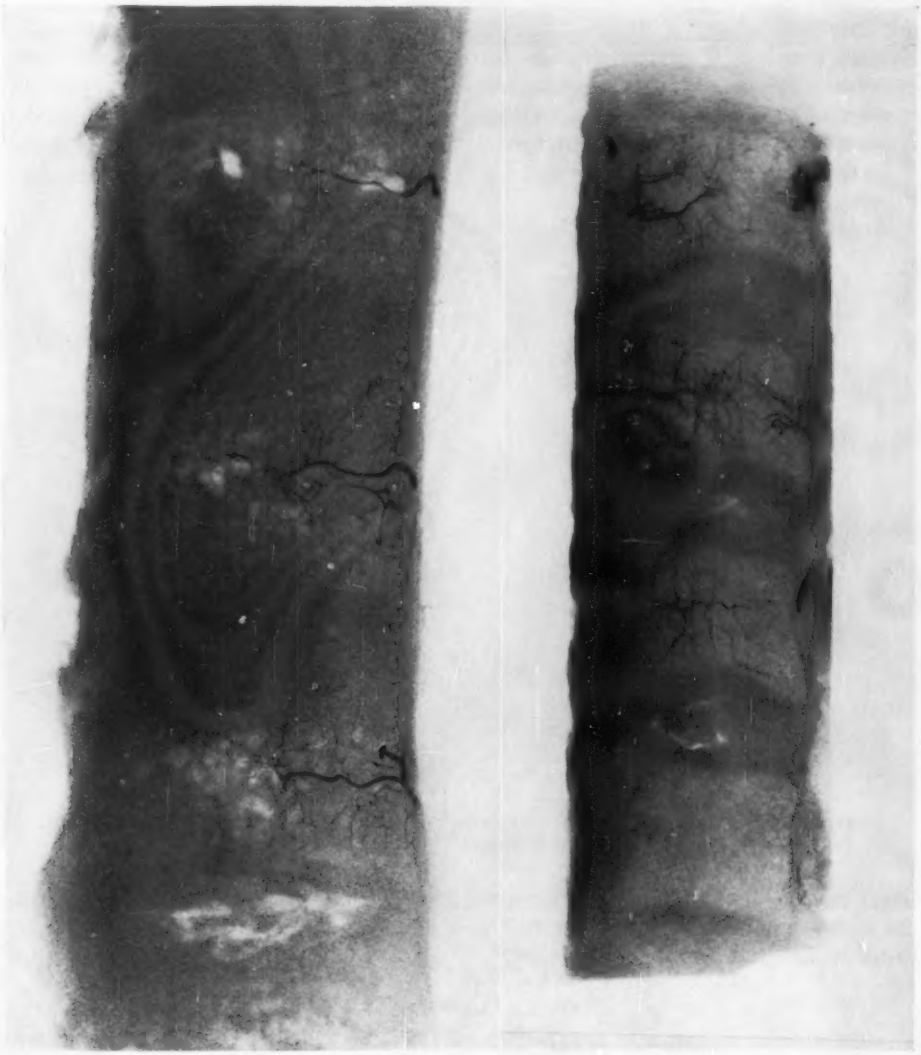

FIG. 4 FIG. 5

Figure 4—Median sagittal section showing main nutrient arteries entering posteriorly. Decalcified specimen.
Figure 5—Median sagittal section showing nutrient vessels. Decalcified specimen.

Further small periosteal and muscular branches, which enter extensive muscular and periosteal anastomoses on the surface of the vertebrae, are present and were the main source of leakage during injection. Figure 1 represents diagrammatically the spinal branches and their main divisions.

The branch to the vertebral body divides into two: one branch passes to the front of the body below the pedicles and lateral masses, lying close to or upon the capsule of the lateral synovial joint of Luschka. The other crosses the body deep to the posterior longitudinal ligament and anastomoses with its fellow of the opposite side. From these horizontal anastomoses, ascending and descending branches link with those above and below on either side of the mid-line, forming a freely communicating arterial plexus deep to the posterior longitudinal ligament (Figs. 2 and 3).

The main blood supply to the vertebral body is from this arterial plexus and enters by the posterior surface. The largest single nutrient vessel is in the mid-line and penetrates the body to about one-half its depth (Figs. 4 and 5). The branches of this vessel pass mainly upwards and downwards towards the disc surfaces, the main stem preserving a fairly constant diameter until it terminates abruptly near the centre of the body (Fig. 6). Smaller vessels also penetrate the posterior surface, at least half the interior of the body being supplied from this aspect.

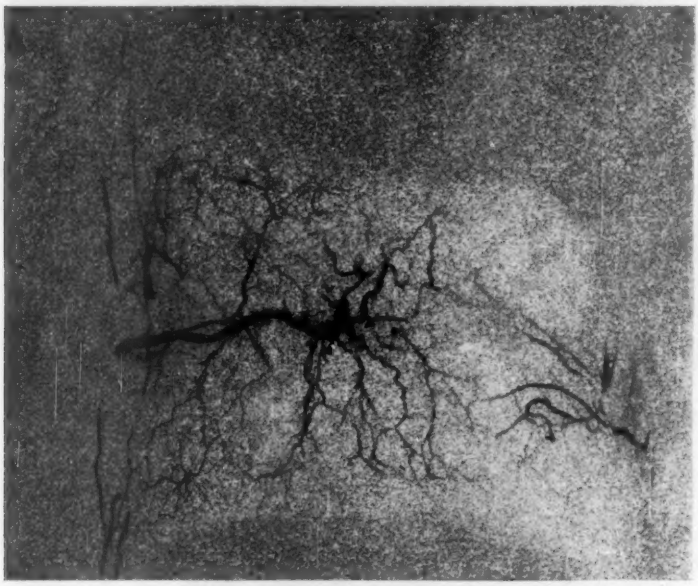

FIG. 6
Enlargement of second vertebra in Figure 5.

The remaining anterior and lateral portions are supplied by the branch passing round on the antero-lateral surface. This supplies one or two lateral branches entering the body below the lateral masses (Figs. 7 and 8) and ends anteriorly in a small mid-line nutrient vessel (Figs. 4 and 5). This pattern of the main nutrient vessels corresponds with that described by Ferguson (1950) in the developing thoracic and lumbar vertebrae.

Comment—The arterial anastomosis deep to the posterior longitudinal ligament is a very free one. Thus the examples shown here were obtained by injection of a single spinal branch and we frequently observed filling of the opposite vertebral artery.

Batson (1942) injected the dorsal vein of the penis in cadavera and live monkeys and demonstrated filling of veins within the pelvic bones, the extradural veins of the spinal canal and veins within the vertebral bodies. He suggested retrograde spread along the veins as the route by which infection and malignant deposits could reach the vertebrae. While

this may explain the spread peculiar to malignant disease of the prostate and other pelvic viscera, the arterial stream should obviously be considered too in the spread of blood-borne disease to the vertebral bodies. Ending in a leash of small vessels with a sudden narrowing

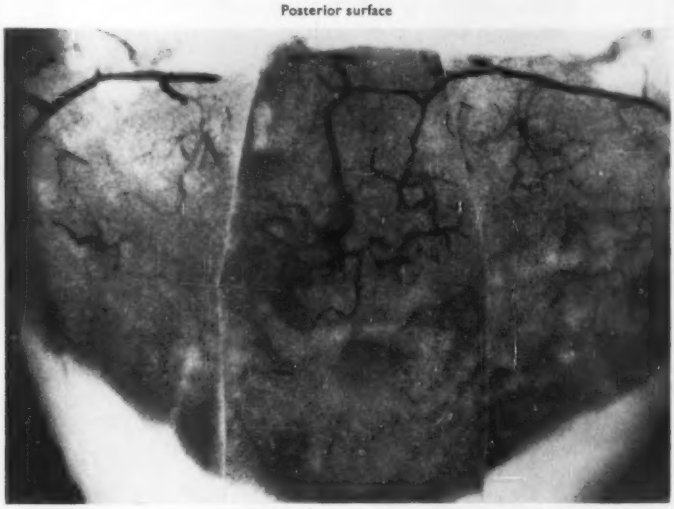

FIG. 7
Radiograph taken from above through whole thickness of vertebral body. Specimen had previously been divided sagittally into three portions.

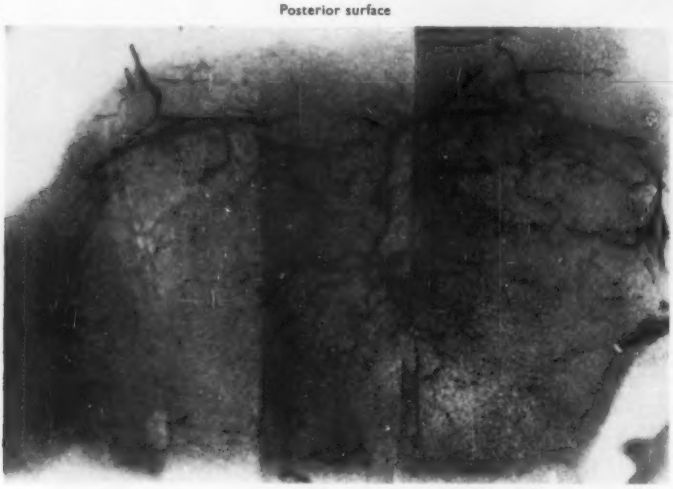

FIG. 8
Similar to Figure 7, but specimen previously divided sagittally into four portions.

of its calibre, the form of the large dorsal nutrient artery is such that larger emboli would tend to be arrested near the centre of the vertebral body. Smaller emboli, such as bacteria, would pass more readily into the branches, and in this respect it is interesting that tuberculous spondylitis often begins subjacent to the intervertebral discs.

SUMMARY

1. The spinal branches of the vertebral artery were injected with a suspension of barium sulphate and the blood supply of the vertebral bodies of the lower four or five cervical vertebrae investigated radiologically.
2. Beneath the posterior longitudinal ligament there is a free dorsal arterial plexus from which a large branch arises to enter the back of the vertebral body. This vessel terminates abruptly at the centre of the body where numerous, much smaller, branches radiate towards the upper and lower surfaces.
3. The possible significance of the form of the intravertebral arteries is considered in relation to embolic lesion in vertebral bodies.

We would like to thank Professor J. M. Yoffey for his encouragement, Dr Norman Brown for the specimens of vertebrae, and Dr G. R. Airth for the radiographs. We also thank Mr Sweet, of Southmead Hospital, Bristol, for the photographic reproductions.

REFERENCES

BATSON, O. V. (1942): The Role of the Vertebral Veins in Metastatic Processes. Annals of Internal Medicine, **16**, 38.

FERGUSON, W. R. (1950): Some Observations on the Circulation in Foetal and Infant Spines. Journal of Bone and Joint Surgery, **32–A**, 640.

HANSON, R. (1926): Some Anomalies, Deformities and Diseased Conditions of the Vertebrae During their Different Stages of Development, Elucidated by Anatomical and Radiological Findings. Acta Chirurgica Scandinavica, **60**, 309.

WILLIS, T. A. (1949): Nutrient Arteries of the Vertebral Bodies. Journal of Bone and Joint Surgery, **31–A**, 538.

THE BLOOD SUPPLY OF DEVELOPING LONG BONES WITH SPECIAL REFERENCE TO THE METAPHYSES

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Humphry (1858) described a dual blood supply to any long bone, periosteal vessels supplying the compact bone and the nutrient artery supplying the marrow. Weinmann and Sicher (1947) pointed out that the nutrient artery also supplied the central part of the metaphysis, its more peripheral parts being supplied by metaphysial arteries derived from the periosteum. Trueta and Harrison (1953) believed that in the adult human femur the nutrient artery did not reach the metaphysial region, which was wholly supplied by metaphysial arteries.

Weinmann and Sicher described the vessels approaching the epiphysial cartilaginous plate, and invading the cartilage, as long hairpin-shaped loops, while Stump (1925) described the opening up of the dilated cartilage lacunae by the activity of syncytial masses of mesenchymal tissue. The peripheral parts of the syncytial masses were said to form osteoblasts applied to the trabeculae, while cavitation, with the formation of lumina, in the centre of the masses produced the extension of blood vessels in the progressively invading tissue.

The purpose of this investigation was to determine the extent of supply of the periosteal vessels and the nutrient arteries in developing long bones and to study the form of those vessels of the metaphyses approaching and invading the epiphysial cartilage plate.

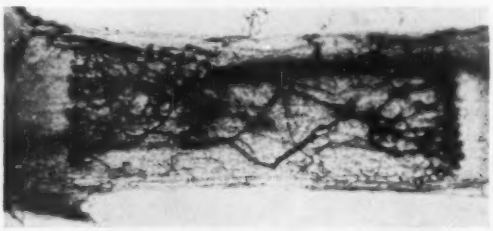


FIG. 1

Metatarsal of an injected twenty-six day rabbit embryo showing nutrient artery giving branches terminating in dilations at the metaphysis of either end. The periosteal plexus of blood vessels can be seen on the surface of the bone. (×35.)

METHODS

Long bones (e.g., tibia, femora, metatarsals) of rabbit embryos and young rabbits, injected with Monastral Fast Blue BNVS paste, were used, the whole bone, 100μ sections, or teased preparations being cleared and mounted. In addition, the phalanges of a human foetus injected with Indian ink were examined.

The injected material was correlated with histological sections of developing rabbit and human bones stained with haematoxylin and eosin, Heidenhain's iron haematoxylin, or Azan.

OBSERVATIONS

During the early stages of ossification of a long bone all the endochondral bone, including the metaphysis, is supplied by the nutrient artery, while some of the periosteal plexus of blood vessels is being included in the developing periosteal bone as its blood supply (Fig. 1).

As the bone grows, more periosteal bone is laid down, and is also supplied by included periosteal vessels, while the endochondral bone is progressively removed to form a medullary cavity containing marrow supplied by the nutrient artery. The more peripheral of those vessels approaching the epiphysial cartilaginous plate are now derived from the periosteal plexus and are the metaphysial arteries, while the central part of the metaphysis is still supplied by the nutrient artery, which runs through the compact bone of the shaft parallel to its periosteal vessels of supply, to enter the medullary cavity (Figs. 2 to 5).

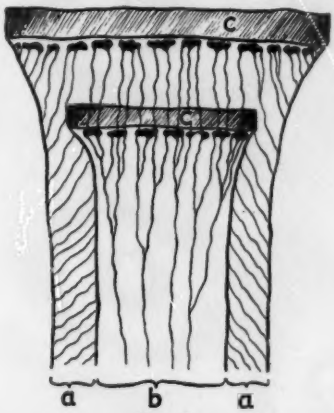


FIG. 2

An early stage in the development of a long bone, with a later stage superimposed. Growth of the bone leads to deposition of periosteal bone, *a*, with its obliquely running periosteal vessels, on the surface of the endochondral bone, *b*, the peripheral parts of the metaphysis come to be supplied by metaphysial arteries derived from the periosteum. Epiphysial cartilage plate, *c*.

The vessels approaching the epiphysial plate, whether derived from the nutrient artery or the metaphysial arteries, have specialised terminations where they meet the plate, with its dilated lacunae. Groups of two or three fine vessels end in a saccular dilation intimately related to the epiphysial plate (Figs. 6 to 8).

Histological sections show that endothelial-walled vessels approach the epiphysial plate and terminate by funnel-shaped endings which open into the dilated cartilage lacunae which thus become filled with blood. Thus, the fine vessels approaching the epiphysial plate in injected specimens are endothelial-walled, and have a peripheral mesenchymal sheath of cells developing into osteoblasts, while their saccular endings are the blood-filled lacunae, unlined by endothelium, opened up in the degenerating cartilage (Figs. 9 to 11).

The same vascular pattern is seen at the advancing margin of ossification in the epiphysis—that is, on all sides of the secondary centre of ossification except at the surface related to the diaphysis.

No vessels were seen traversing the epiphysial cartilaginous plate, from diaphysis to epiphysis, at any stage.

DISCUSSION

The compact periosteal bone of the shaft of a developing long bone is supplied by vessels running an oblique and parallel course through the compact bone and derived from the periosteal plexus of blood vessels, while the endochondral bone, until its removal, is supplied

FIG. 3

FIG. 4

Figure 3—Injected tibia of a thirty-seven day old rabbit showing nutrient artery entering bone parallel to the obliquely running periosteal vessels supplying the compact periosteal bone of the shaft. (×30.) Figure 4—Upper extremity of injected tibia of a thirty-seven day old rabbit. The blood supply of the peripheral part of the metaphysis from periosteal vessels can be seen. (×3.)

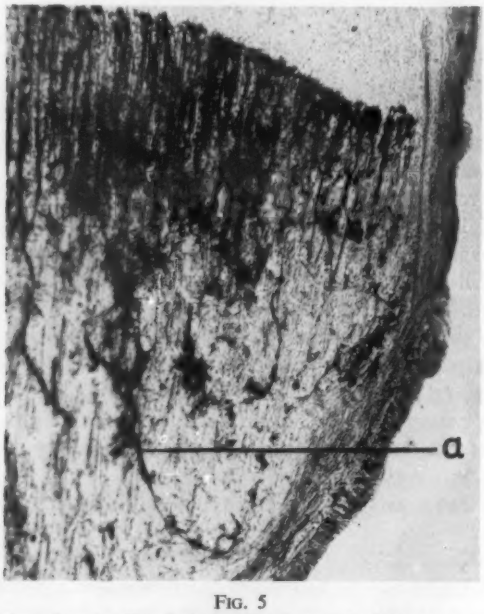


FIG. 5

Same bone as Figure 4, showing a metaphysial artery, *a*, entering from the periosteum. (×35.)

by the nutrient artery. In the later stages the nutrient artery supplies the bone marrow of the medullary cavity. The metaphysis is at first supplied by the nutrient artery only, but as the bone grows metaphysial arteries derived from the periosteum take over the blood supply of the peripheral parts of the metaphysis to an ever-increasing extent. Thus, Trueta and Harrison (1953) found no evidence that the nutrient artery supplied any blood to the metaphysial region in the adult femur (Fig. 2).

FIG. 6

Teased preparation of injected metaphysis of a twenty-six day rabbit embryo tibia showing the saccular dilations on the vessels eroding the epiphysial cartilage plate. (×110.)

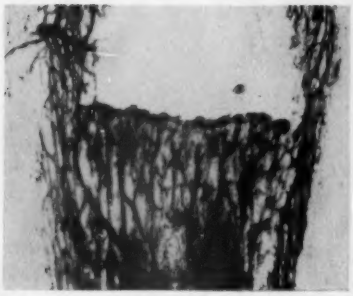


FIG. 7

FIG. 8

Figure 7—Showing the line of saccular dilations on the vessels where they are related to the epiphysial cartilage plate. Injected tibia of twenty-six day rabbit embryo. (×35.)
Figure 8—Another 100μ section of same bone as in Figure 7. (×100.)

Blood cells fill the dilated cartilage lacunae at the line of advancing ossification and the blood itself is apparently in direct contact with the cartilage and may play a part in eroding the columns of dilated cartilage cells. In the wake of this process a layer of osteoblasts lined by a layer of endothelial cells extends up the inner walls of the cartilaginous tubules so formed, thus progressively forming endothelial-walled vessels in the new-formed bone. The saccular dilations of injected specimens at the line of cartilage invasion are blood-filled lacunae and no endothelial layer is observed lining their cartilaginous walls.

The periphery of each secondary centre of ossification advances in similar fashion and at the end of growth the vascular loops, as described by Trueta and Harrison, beneath the

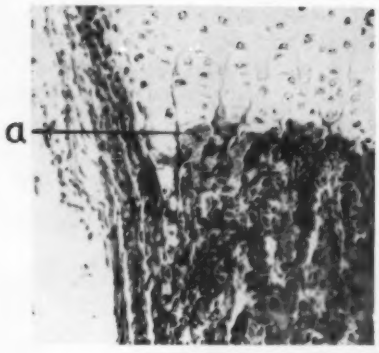


FIG. 9

Section of metaphysis of tibia of a twenty-six day rabbit embryo showing blood-filled lacunae, *a*, corresponding to the saccular dilations shown in Figures 6, 7 and 8. Stained with Heidenhain's iron haematoxylin, 8μ section. (×80.)

adult articular cartilage, are perhaps derived from the vessels and their saccular dilations by completion of the endothelial walls.

Since the blood is confined at the line of advancing ossification of the metaphysis only by walls of fragile calcified cartilage, trauma to the region would readily produce small haematomata which, as has been suggested, might act as a nidus for infection. If the vessels were of the hairpin-like form usually described, the occurrence of such haematomata would be less readily explained. Alternatively, as the terminations of the vessels are dilated and saccular, blood flow in them would be sluggish and emboli might, therefore, easily settle in this situation.

SUMMARY

1. Periosteal bone is supplied by periosteal vessels and endochondral bone by the nutrient artery.

2. In the earliest stages of development the metaphysis is supplied by vessels derived only from the nutrient artery. Later, metaphysial arteries derived from the periosteum take over the supply of its peripheral part, the extent of their area of supply progressively increasing.

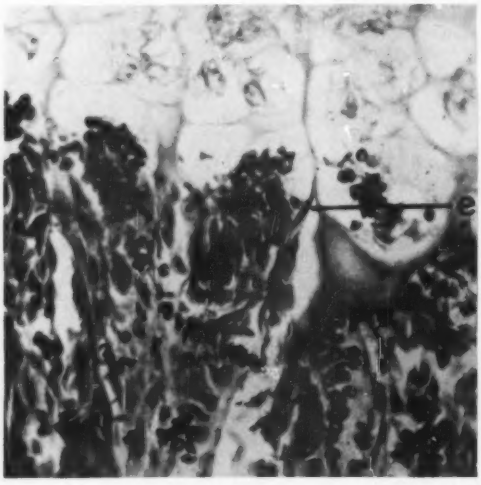


FIG. 10

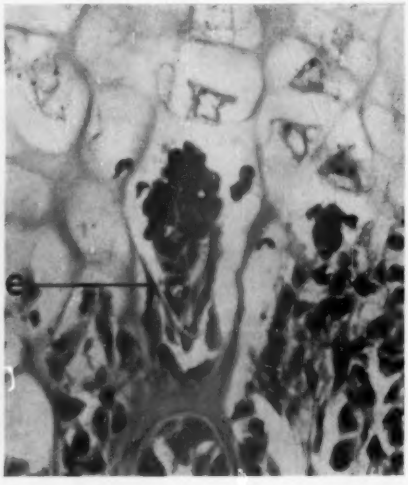


FIG. 11

Figure 10—Section of metaphysis of a twenty-five day rabbit embryo tibia. Blood cells are seen lying free in the lacunae without the intervention of an endothelial wall. *e*, endothelial cell. 8μ section. Heidenhain's iron haematoxylin. (×330.) Figure 11—The same bone as in Figure 10, again showing the unlined blood-filled lacunae at the termination of a vessel which opens in funnel-like fashion into the lacuna. *e*, endothelial cell. (×500.)

3. In injected specimens the blood vessels approaching the epiphysial cartilaginous plate end in saccular dilations. Histological sections show these dilations to be blood-filled cartilage lacunae, with no endothelial lining and into which open the blood vessels approaching the epiphysial plate.

I would like to thank Professor D. V. Davies for valuable advice and criticism, Mr G. Maxwell for technical assistance and Mr J. S. Fenton and Mr A. L. Wooding for the photographs.

REFERENCES

HARRIS, H. A. (1929): The Vascular Supply of Bone, with Special Reference to the Epiphysial Cartilage. Journal of Anatomy, **64**, 3.

HARRIS, H. A. (1933): Bone Growth in Health and Disease. London: Humphrey Milford, Oxford University Press.

HUMPHRY, G. M. (1858): A Treatise on the Human Skeleton. Cambridge: Macmillan and Co.

KEITH, A. (1919): Studies on the Anatomical Changes which Accompany Certain Growth-disorders of the Human Body. Journal of Anatomy, **54**, 101.

PAYTON, C. G. (1934): The Position of the Nutrient Foramen and Direction of the Nutrient Canal in the Long Bones of the Madder-fed Pig. Journal of Anatomy, **68**, 500.

STUMP, C. W. (1925): The Histogenesis of Bone. Journal of Anatomy, **59**, 136.

TRUETA, J., and HARRISON, M. H. M. (1953): The Normal Vascular Anatomy of the Femoral Head in Adult Man. Journal of Bone and Joint Surgery, **35–B**, 442.

WEINMANN, J. P., and SICHER, H. (1947): Bone and Bones. Fundamentals of Bone Biology. London: Henry Kimpton.

PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN AND ITALY

BRITISH ORTHOPAEDIC ASSOCIATION

AUTUMN MEETING, 1956

The autumn meeting of the British Orthopaedic Association was held in Italy under the auspices of the Societa Italiana di Ortopedia e Traumatologia on October 1–7, 1956.

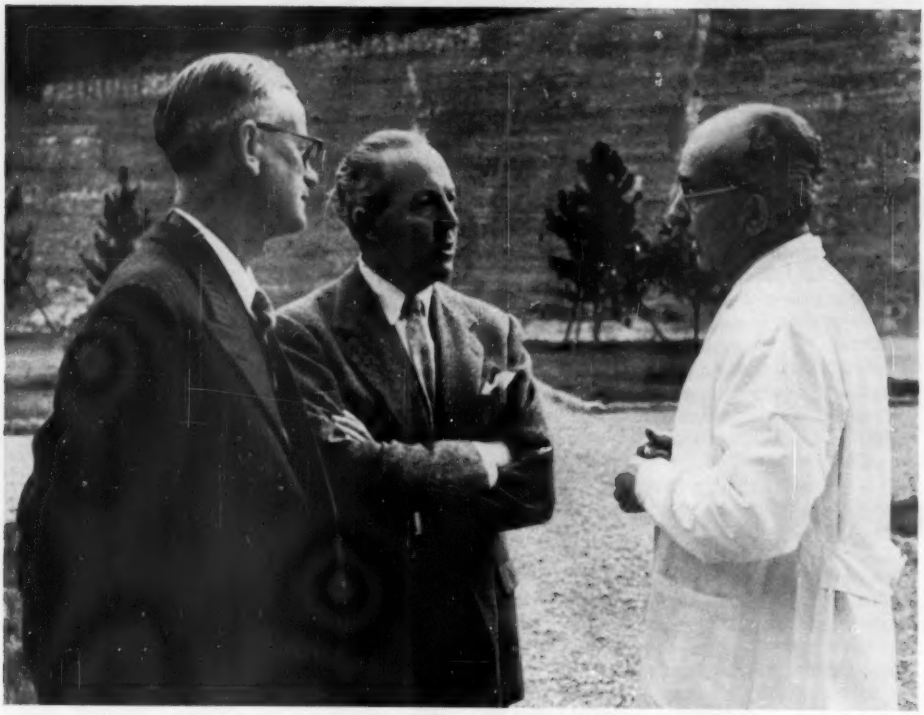
The meeting opened in Rome in the magnificent lecture hall of the Clinica Ortopedia dell' Universita', where Professor Marino-Zuco rules a realm of considerable splendour. The hall was equipped with every conceivable aid to speaker and audience; simultaneous interpretation into English of speakers in Italian was available through headphones and was admirably done. Greetings were extended to the visitors by Professor C. Marino-Zuco, Professor P. Del Torto, the president of the Italian Society, and Professor V. Puntoni, Dean of the Faculty. Our sense of importance was further titillated by the attentions of official photographers who did not hesitate to floodlight their prospective victims.

A tour of the Clinic gave additional evidence of the magnificence of the equipment at its disposal, including an electron microscope with a direct viewing screen. In the wards a selection of patients were seen, including a group with congenital dislocation of the hip irreducible by closed methods, who had been treated by open reduction and acetabuloplasty with the temporary interposition of an acrylic cup which was removed some months later when a cartilage lining had formed in the new acetabulum.

Treatment of length discrepancy of the lower limbs—*Professor C. Marino-Zuco* (Rome), opening a discussion, said that the problem could be approached in four ways: by attempting to stimulate the growth of the short limb or to reduce that of the long limb, by mechanical shortening of the long limb or finally by mechanically lengthening the short limb. Of the last two, mechanically shortening a limb in the adult he thought unsatisfactory because it deformed the healthy limb and because the muscles of adults had difficulty in adapting themselves to their reduced length. He therefore preferred leg-lengthening and had worked on devices to stabilise a long Z-osteotomy during the necessary distraction. By model and film he then demonstrated his present method, which he had used on twenty-one patients since 1952. He performed a long Z-osteotomy of the femur in the coronal plane and after reaming the medullary cavity to permit the nail to slide freely, he inserted a U-shaped Küntscher nail modified by the attachment of a long thin strip of steel to the upper end. This strip lay in the U-groove and was brought out of the medullary cavity at the upper level of the osteotomy to be threaded through a stout pin held in position across the osteotomy site by a retaining band passing behind the bone. The pin projected from the wound after suture and passed through a plate containing a pivot with a non-return ratchet. This plate was embodied in a short plaster spica. When the pin was turned with a special key the Küntscher nail was forced distally, sliding in the medullary cavity of the upper fragment. The lower fragment was thus pushed distally by the nail, a cross-stop on the nail at the level of the lower end of the Z preventing further penetration towards the knee. Elastic traction applied to a Steinmann pin through the upper tibia reduced pressure on the epiphyses at the knee.

About two centimetres was usually gained at the time of operation, and by the end of a month a gain of five or six centimetres was readily attained. The lengthening was under strict control and was said to involve little suffering for the patient. After a month the wound was reopened and the distraction device removed; but the nail was left in position and bone grafts were applied to the defects left in the elongated Z above and below. Protection for one to two years was necessary until full consolidation was attained, when the Küntscher nail, but not the encircling wires used to hold the bone grafts, was removed. He preferred if possible to overlengthen the short limb in children to compensate for later overgrowth of the sound limb. *Professor J. Trueta* (Oxford) spoke on direct control of the rate of growth. It was easy to prevent growth of the normal limb, but this was much less attractive than stimulating growth in the stunted limb. He had noted that osteomyelitis led to overgrowth of the affected bone only if the shaft was involved; infections in the metaphysial regions produced either no effect or undergrowth. Similarly overgrowth of the femur after fractures in childhood followed only those fractures of the shaft with overlapping of the bone ends. He thought that in each

Rome. Professor C. Marino-Zuco, Mr Philip Wiles, Professor V. Puntoni, Professor P. Del Torto.



Bologna. Mr Philip Wiles, Professor J. Trueta, Professor R. Zanoli.

case it was due to interference with the nutrient artery, an opinion supported by animal experiments. He now had experience of twenty-six human subjects in whom he had blocked the central medullary cavity with a boiled bone graft. While others using similar methods had attained lengthening up to five centimetres, his limit so far was three and a half centimetres. The method was still in the experimental stage and full of variables. *Mr R. I. Stirling* (Edinburgh) asked Professor Marino-Zuco what complications had arisen with his method, and in particular whether he had had any later trouble with the lower femoral epiphysis either from pressure or from the presence of the nail, and whether his patients had suffered later osteoarthritic changes in the knee joint, which he had found very commonly in his own series. He did not think that adequate protection from undue pressure between the joint surfaces was provided by the method demonstrated. *Mr K. I. Nissen* (London) said that so far as leg inequality in the fully grown patient was concerned he preferred to shorten the sound limb, as bone lengthening was open to too many complications. This might be regarded as a defeatist attitude, but bone shortening was easy and safe, quicker for the patient and a better procedure for use by the surgeon only occasionally involved in the problem. In the tibia he did a long oblique resection, fixing the bone ends subsequently with two screws. In the femur he operated in the subtrochanteric region, fashioning a projecting peg on the outer cortex of the lower fragment which he inserted into the medullary cavity of the trochanteric region. A short curved plate then gave adequate fixation within a plaster spica, and union was rapid. He had had no trouble attributable to the resultant muscle shortening. *Professor Marino-Zuco* felt that Professor Trueta's method was laudable, but unfortunately it was still unpredictable. With regard to the dangers of his own method he had as yet had no trouble from infection. With regard to epiphysial disturbance the pin must not reach the femoral epiphysis, and in any case it only stayed there a short time. There was a danger of fracture if the nail was removed too early. Weight bearing stimulated bone reformation, but prolonged protection was necessary. He had had no trouble attributable to direct pressure at the knee joint; applying elastic tibial traction with the knee somewhat flexed he thought gave adequate protection. If the disparity of leg length was small (less than four centimetres) bone lengthening by his method was so easy that he would never think of shortening the good limb, though a combination of the two might be usefully applied in cases of gross inequality. Women would of course readily accept a high heel, and if the subject was tall she often preferred to be shorter.

Operative techniques—On October 2, members in the lecture theatre were able to watch on a large screen operations televised from the theatres. A femoral bone-lengthening of the type discussed on the previous day was performed with masterly skill, and an intracapsular fracture of the neck of the femur was fixed with a compression screw.

The surgical treatment of scoliosis—*Professor Marino-Zuco* related his experiences with thirty-five patients studied during the last three years, both adults and adolescents, and mostly with severe uncompensated curves with markedly lowered vital capacities. In some the intervention was purely to prevent later deterioration, and in any case one's expectations of amelioration must be limited. It was essential to maintain a correct balance between the respective curves, and there was a danger of stretching the cord if severe curves were forcibly corrected. No preliminary correction of curves was attempted; a few days in bed before operation sufficed to relax the structures. In principle his method was first to do a decostation—that is, a thoracoplasty to remove the rib gibbus. This must extend sufficiently cephalad to permit the scapula to drop back into its normal relationship, and transverse processes of severely rotated vertebrae might need removal also. He then inserted a divaricator on the concave side of the curve; various patterns were illustrated, the transverse processes being the usual purchase points. On the convex side various forms of retractors (really " contractors ") were applied to ribs or transverse processes. The use of these retained metal devices did not preclude the necessity of spinal fusion and bone grafting. The secondary lumbar curve was treated on similar principles, often before the assault on the major curve. The method was applicable to all sorts of scoliosis—idiopathic, paralytic and congenital. He thought the effect on the fixed curves of older subjects was sometimes impressive; and, as illustrated in a series of slides, the disappearance of the rib gibbus was often cosmetically most satisfactory.

Mr J. I. P. James (London) voiced the sentiments of many of the visitors with his opening remark, which he felt should be borne in mind by every surgeon treating scoliosis—" Is my operation really necessary? " He reviewed what he felt at present should be the indications for operation. One must consider the hopes 1) of correcting existing deformity, and 2) of preventing later deformity or disability. We could correct a dropped shoulder and a prominent hip, but not rib rotation. The former two, however, must be bad enough to warrant interference, and any correction attained we must be able to maintain. We are learning which curves will deteriorate sufficiently to warrant preventive measures.

In discussing the various types he thought the lumbar curves never needed correction on cosmetic grounds, though later osteoarthritic pain might warrant fusion. Of the thoraco-lumbar curves but

few were ugly, and not more than 10 per cent needed correction and fusion—usually when mature but earlier if increasing rapidly. The infantile idiopathic curves almost always carried a bad prognosis and eventually needed fusion. In the common idiopathic thoracic curves, about 50 per cent needed intervention after the age of ten, and all who at this age had a curve of 80 degrees or more. Of the double curves, the bad ones were not much helped by operation, though it made the patient a little taller. Only 5 per cent of them deteriorated severely, and the selection of cases for prophylactic fusion was therefore difficult. Prognosis in the short sharp curves of neurofibromatosis he thought was always bad; they should be corrected and fused early, but fusion was difficult to obtain in this condition.

In paralytic scoliosis prognosis was usually bad, and matters were made worse by the element of fatigue. High rib rotation seen in this type was bad as it could not be concealed by the dressmaker. Operation did not improve the appearance but it did prevent deterioration and so should be done early. Curves of 70 degrees or more at the age of ten almost always needed surgery. In kyphoscoliosis there was a grave danger of paraplegia and a prophylactic fusion should therefore be done early.

In all types operation should if possible be deferred until after the age of ten. With the introduction of the Milwaukee brace it was now possible in the infantile type to prevent deterioration, and sometimes even to reduce the curvature, until the age when fusion was advisable.

With regard to the rib "gibbus" attempts at correction had been made for many years but usually with little improvement because in severe cases rotation was so marked that the bodies of the vertebrae underlay the ribs instead of lung. Special "silhouette" radiographs would show whether thoracoplasty was worth while.

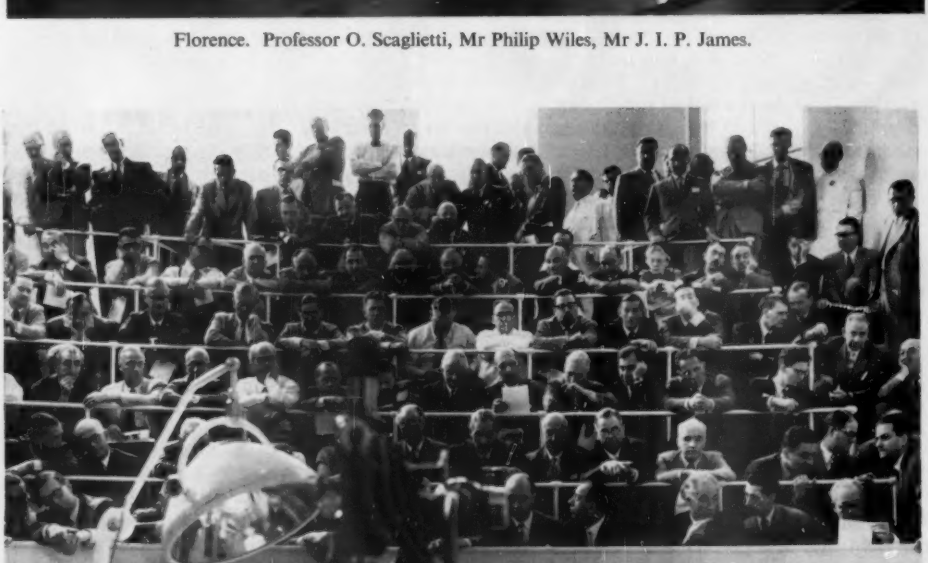
Professor Marino-Zuco said he agreed with most of Mr James's sentiments but felt that earlier age limits could be applied. He felt that lumbar curves, especially those to the left, should be operated on as early as possible, and excused his later interventions in this type on aesthetic grounds. He felt that thoracoplasty for the rib gibbus, if done sufficiently high and combined with disarticulation of the ribs and resection of the transverse processes, greatly improved the position of the scapula, and he had found the vital capacity to have been improved by the increased mobility of the chest wall.

October 3 and 4 were spent by the visitors as the guests of *Professor R. Zanoli* at Bologna. A tour of the Instituto Ortopedico Rizzoli, that Mecca of foreign surgeons, more than lived up to the expectations of those of us who had not visited it before; Codivilla, Putti, Delitala—names to conjure with—were brought to reality. Professor Delitala himself honoured the meeting with his presence. The library in the old part of the monastery with its lovely view over Bologna and the quiet of Putti's own library, in which he always managed to work for an hour every day, held us in thrall. In the workshops the technicians had stayed late to demonstrate the immense variety of apparatus, appliances and prostheses that they produce.

In an operating session of two and a quarter hours Professor Zanoli demonstrated his mastery of surgery. A fractured neck of femur was first fixed with a compression screw. Then a transfer of part of the external oblique to replace gluteus medius in a patient with poliomyelitis was performed, a two-inch band of the aponeurosis of the muscle being passed through a hole in the greater trochanter, wide abduction of the hip being maintained subsequently for one month. The third case was a reduction arthrodesis of a congenitally dislocated hip with compression-screw fixation and ilio-femoral graft in a girl of fourteen. The femoral head had previously been pulled down to the level of the acetabulum by skeletal traction applied to the femur during the previous month. The fourth patient had a giant-cell tumour of the lower end of the femur, proved by frozen-section biopsy before a local resection of the femur was performed, the space between femur and tibia being filled with a frozen calf bone graft from the bone bank. Finally a spiral fracture of the tibia was used to demonstrate the perfection of the position already attained by traction by the application of direct pressure to the bone by the Delitala technique. During the radiographic control of the above procedures radiographs on paper were returned for inspection within forty seconds of exposure.

In the lecture hall of the Institute *Dr C. Camurati* presented a series of fractures treated by the Delitala technique with long-term results. *Dr R. Zanasi* showed a number of patients who had had tumours of the lower femur and upper tibia treated by local resection and replacement by calf bone. Twelve patients had now been treated in this way. Consolidation had not always occurred but in some instances it was satisfactory in as short a period as three and a half months. Two recurrences had occurred around but not in the graft. *Dr G. Lanciotti* demonstrated the results of reduction arthrodesis in cases of unilateral dislocations of the hip (as shown in the operating session) in a series of neglected lesions. In twenty-nine of thirty-one cases fusion had occurred satisfactorily. *Dr G. Repaci* demonstrated the late results of the external oblique-gluteus medius transfer in a series of fifty patients operated upon in the last three years, and *Dr A. Dal Monte* some results achieved in the treatment of scoliosis by resection of the rib "gibbus" and vertebral arthrodesis with calf bone.

Florence. Professor O. Scaglietti, Mr Philip Wiles, Mr J. I. P. James.



Watching an operation at the Rizzoli Institute, Bologna.

The assembled group at the 1956 meeting at Bologna.

A photograph taken during the meeting of the British Orthopaedic Association at Bologna in 1924. Professor Vittorio Putti is seated on the ground in white coat. Sir Robert Jones is sitting behind him, near the middle of the second row.

Professor Ing. Scalas and *Dr V. Benassi* showed an impressive series of amputees and their prostheses, those of the forearm controlling their prostheses by rotation or by powerful Krukenberg stumps. In the lower limb the self-retaining below-knee prosthesis and that used after disarticulation of the hip were especially striking. *Dr G. Lorenzi* demonstrated some fine results of knee arthroplasty with fascia lata interposition done for old gonococcal arthritis. Finally an admirably constructed film of various tendon transfers for poliomyelitis of the lower limb was shown, largely the work of Professor Zanoli's senior assistant, *Dr A. Picchio*. As a demonstration of the techniques selected it could scarcely have been bettered.

Medal struck to commemorate the Italo-British orthopaedic meeting. The medal, bearing the effigies of Vittorio Putti and Robert Jones, was generously presented by Professor Scaglietti to every member of the British Orthopaedic Association who attended the meeting. Cast in bronze and having a diameter of 9 centimetres, it was made by Aurelio Mistruzzi.

On October 5–7 the Association enjoyed the delightful hospitality of *Professor O. Scaglietti* in Florence. They were first greeted in the Palazzo Vecchio by the Mayor of Florence and the Magnificus President of the University, who stressed in complimentary terms the place that orthopaedics held in the growth of culture and the humanities. The first scientific session was held in the beautiful Salone dei Duecento where *Professor Scaglietti* demonstrated a variety of patients. There were a number of excellent results obtained by various procedures in congenital dislocation of the hip. His results in established Volkmann's contracture by a combination of muscle slide, tenolysis and neurolysis could scarcely have been surpassed, and he showed an example of bilateral paralysis of the scapular muscles in a myopathy treated by bone fusion of one scapula to the other; two-thirds of the normal range of movement was retained with excellent power, and there was little functional disability. He also showed a number of examples of non-union of the femoral neck treated by a very obliquely placed compression screw, and of local resection of tumours and other destructive lesions of bone with bone graft replacement; the results were impressive. Both at the Salone and in a later tour of the Instituto Ortopedico Toscano there was an instructive exhibition of radiographs, and at the Instituto cases of muscle transplant in the paralysed lower limb and of arthroplasty of the knee with fascia lata interposition were demonstrated. The latter were in young subjects, most of them suffering the after-effects of gonococcal arthritis, and the results were superb.

The restricted space available at the Instituto Toscano owing to the rebuilding programme prevented all the members of the Association from attending an operation session by Professor Scaglietti on October 6. In a girl of eight years with a congenital subluxation of the hip he performed an open reduction after excision of the limbus and Z-lengthening of the iliopsoas; a " shelf " was turned down and fixed in position with a graft taken from the wing of the ilium. A Volkmann's ischaemic contracture following a Monteggia fracture was mobilised, using a modification of the Max Page technique. Through a medial incision, after freeing of the ulnar nerve from its groove, all structures on the flexor aspect of the forearm were detached from the elbow region and from almost the full length of the ulna, interosseous membrane and radius. This successfully released the contracture. An extensive neurolysis and tenolysis in the scarred area in the middle third of the forearm completed

a masterly performance. Finally a bilateral congenital dislocation of the hip in an infant was reduced with facile gentleness.

Arthroplasties and hemiarthroplasties with interposition of Gelfoam—*Professor L. Giuntini* (Siena) spoke on this technique. He thought its advantages derived from three sources: first, it was haemostatic to the raw bone surface; secondly, it prevented new bone formation; and thirdly it eventually liquefied to a state not unlike synovial fluid. In the elbow, knee and ankle he had found it very satisfactory, but less so in the hip. He showed films demonstrating the technique and an excellent result in an arthroplasty of the elbow, and another showing the technique in arthroplasty of the hip.

Surgical treatment of solitary cartilaginous tumours of the skeleton—*Professor Carlo Pais* (Genoa) said that these tumours developed rapidly in youth, slowly in adults. Local recurrence was common, and malignant change occurred in 10–15 per cent. The tumours were usually well encapsulated and metastases occurred rarely and late. Radical local surgery was indicated; amputation was seldom required except in recurrent or frankly malignant cases, and bone grafts with intramedullary fixation should replace defects made by local resection. Tumours in short and flat bones were best treated by excision of the entire bone. An excellent film showed the tangential resection of a massive chondroma of the femoral neck, and a second case of a chondrosarcoma in the same region involving the external iliac and femoral vessels, a segmental resection of a chondrosarcoma of the tibia, and an excision of the scapula for local sarcomatous change in multiple chondromatosis.

Resection-arthrodesis of the major joints—*Dr Bruno Calandriello* (Florence) said that with few exceptions metallic internal fixation was avoided and reliance placed on adequate resection of the joint, good apposition of the raw surfaces, a bone graft obtained locally, and sound and extensive plaster fixation. In wrist, elbow, shoulder, ankle and knee consolidation was obtained in every case. The technique used in the hip was demonstrated with a film; of 232 cases only nine had failed to consolidate after the first operation. Three patients refused a second operation, but fusion was obtained in the remaining six at a second intervention.

Diaphysial fractures of long bones treated at the Instituto Ortopedico Toscano—*Dr G. Stringa* (Florence) demonstrated the beautiful reductions and excellent results that can be obtained by closed methods without the use of metallic internal fixation. In the lower limb and sometimes in the upper limb preliminary traction by a Kirschner wire for ten days preceded definitive reduction and plaster fixation. The average time of union was no greater than by other methods, except perhaps in the tibial fractures. A film, not least remarkable for its musical background, illustrated the methods used.

Surgical treatment of congenital subluxation of the hip—*Dr G. F. Fineschi* (Florence) believed that of the indications for any particular treatment age was the most important. Once the first few years of life were past, the following procedures were used. 1) Under fifteen, either a shelf operation after open reduction, or a varus osteotomy of the femoral neck, the second being increasingly favoured. 2) Over fifteen, either a varus osteotomy or arthrodesis. 3) In adult life, arthrodesis with osteotomy. This paper was also illustrated by a film of the highest quality.

Throughout this most successful tour we and our wives were the happy recipients of hospitality dispensed on the most lavish scale. Our hosts had taken endless trouble not only to make the scientific sessions enthralling but to make our every moment a pleasure both to the eye and, let it be admitted, gastronomically. It is difficult to find words to express our thanks adequately, but to Professor and Sra Marino-Zuco, to Professor and Sra Zanoli, to Professor and Sra Scaglietti and to all their assistants we extend our heartfelt gratitude and the hope that they will not long deny us an opportunity in this country of repaying to them some small part of our heavy debt.

OFFICERS FOR 1957-58

The following were elected: *Vice-President*—Mr H. J. Seddon (London); *Honorary Secretary*—Mr J. I. P. James (London); *Members of the Executive Committee*—Mr John Adams (London), Mr Mervyn Evans (Swansea), Mr J. C. Scott (Oxford) and Mr F. G. St Clair Strange (Canterbury).

Mr Norman Capener (Exeter) was elected President for 1958-59.

ELECTION OF FELLOWS, MEMBERS AND ASSOCIATES

At a Meeting on September 30 the following were elected.

Member:

Hugh C. Barry (Sydney)

Associates:

K. R. J. de Belder (Nocton)
Sheroo Bharucha (Birmingham)
D. C. D'Netto (Sunderland)
R. Esteve (Barcelona)
J. S. J. Morley (Manchester)
M. A. Vali (Ipswich)

VISIT OF THE 1956 BRITISH TRAVELLING FELLOWS TO THE UNITED STATES OF AMERICA AND CANADA

" AN ORTHOPAEDIC ODYSSEY "

The " Queen Mary " sailed from Southampton on May 3, 1956, bound for New York. Included among her passengers were four of the five Exchange Travelling Fellows of the British and New Zealand Orthopaedic Associations: D. L. Evans from London, A. G. Quinlan from Glasgow, W. J. W. Sharrard from Sheffield and O. R. Nicholson from Auckland, New Zealand.

After an uncomfortable five days with " fresh gales and heavy seas," the sun shone for the first time as Long Island appeared on the horizon. There can be few more perfect approaches to any country than that to America by way of the Hudson River. Leaving the Statue of Liberty to port and the massive skyline of Manhattan to starboard, the " Queen Mary " docked at Pier 90 in the heart of New York. There we were joined by J. S. R. Golding from Jamaica, the fifth member of our party.

Standing—O. R. Nicholson, J. S. R. Golding, W. J. W. Sharrard.
Sitting—A. G. Quinlan, D. L. Evans.

May 8-9, 1956. NEW YORK.

We were met by Dr L. R. Straub and Dr T. C. Thompson—a welcome indeed. The next day we visited Wall Street to collect invaluable dollars, disregarding Dr Mather Cleveland's advice. " Put your hands in front of your eyes, boys, don't look at capitalism." Though no formal programme was planned we visited the recently rebuilt Hospital for Special Surgery and attended a staff conference at which Dr McLaughlin spoke on shoulder dislocations.

The welcoming dinner at the Harvard Club was the highlight of our brief stay in New York. Under the chairmanship of Dr Philip D. Wilson, there were gathered to meet us a most distinguished group of American orthopaedic surgeons, including Dr Paul C. Colonna, President of the American Orthopaedic Association, who with several others had flown long distances to be present. It was a memorable evening and a wonderful welcome to five young British orthopaedic surgeons to be greeted by such a galaxy of surgeons, whose names are equally well known on both sides of the Atlantic.

From New York until our journey from Edmonton to the Canadian Rockies, we travelled exclusively by air. So much occurred within the next seven weeks that it is possible to comment only briefly on a few features at each centre. It is not possible to mention by name all our hosts and hostesses or to describe their delightful homes where we were so kindly entertained. It must suffice to record that throughout the hospitality was phenomenal and quite overwhelming.

May 10, 1956. BUFFALO (New York)

Met by Dr B. E. Obletz and colleagues, we crossed the Peace Bridge and drove along the Canadian shore to Niagara Falls. The Horseshoe and American Falls are a wonderful sight, the Horseshoe Falls being the more impressive because of their size, shape and the unbroken fall of water.

May 11–12, 1956. CLEVELAND (Ohio)

Under the aegis of Dr James A. Dickson (who bears a marked resemblance to pictures of Sir Robert Jones) and Dr C. H. Herndon, we visited the University Hospitals, Highland View Hospital, Rainbow Hospital and St Luke's Hospital, at each of which programmes had been planned. Among the many interesting discussions held and subjects presented, we were very impressed with the results of a conservative operation in slipped femoral epiphysis with severe displacement shown by Dr C. H. Heyman. In brief, this entails refashioning of the neck of the femur by removal of the bony prominence at the junction of neck with the displaced head, which obstructs movement by impingement against the rim of the acetabulum. Epiphysiodesis by means of a central graft insures against still further displacement when consolidation is incomplete. Dr M. A. Brahms introduced us to selective plantar neurectomy in the treatment of pes cavus, about which we were to learn more in Indianapolis. Dr J. A. Dickson and Dr Kendrick discussed the " unsolved fracture." They emphasised the value of a nail plate in the primary treatment and the importance of early recognition of delayed or non-union. Early cancellous grafting and when necessary some variety of osteotomy to alter a high angle fracture line were indicated in such cases. Dr J. Strong showed some motion pictures of superb quality which he had himself made.

We watched a Major League ball game and saw the Cleveland Indians massacre Kansas City. Baseball appeared a relatively straightforward game and apart from the finer points could be appreciated by the novice. The enthusiasm of the crowd was colossal. One hour after we flew from Cleveland it was hit by a tornado and all flying was cancelled for thirty-six hours.

May 13–15, 1956. INDIANAPOLIS (Indiana)

Dr J. Neil Garber, who had flown to New York to greet us, welcomed us again in Indianapolis and joined us finally at Banff. He had played a large part in arranging our tour and we cannot adequately express our thanks to him.

Conferences and scientific programmes were held at Riley Hospital, Long Hospital and Veterans' Administration Hospital. We were particularly interested in hearing further from Dr G. J. Garceau about selective plantar neurectomy. The results were most impressive. His paper on this subject appears in the June number of the *Journal of Bone and Joint Surgery* (Vol. **38–A,** 563). Among many interesting presentations were those on myasthenia gravis by Dr J. E. Tether and surgery in spastic paralysis by Dr C. D. Martz.

We visited the Indianapolis motor speedway and the Eli Lilly plant, and were entertained to an out-of-season " Thanksgiving Day " Dinner complete with turkey, cranberry sauce and pumpkin pie.

May 16–17, 1956. MILWAUKEE (Wisconsin)

At Milwaukee we met Dr W. P. Blount and Dr A. C. Schmidt, both Professors of Orthopaedic Surgery in the University of Wisconsin.

Among many subjects, scoliosis and the use of the Milwaukee brace were naturally discussed. When spinal fusion is indicated it is now their custom to remove the brace after correction, to operate, and then to replace it. They are prepared to undertake spine fusion at any age and have seen no evidence of developing lordosis.

We were introduced to abdominal fascial transplants. Though we were to learn more about these from Dr Lowman, it was convincing to learn of the enthusiasm of other surgeons for this procedure. The basic criss-cross transplant from one iliac crest to the opposite last fixed rib confers anterior abdominal stability and also other less easily assessable qualities. Lateral abdominal transplants have a place as " hip shruggers " or " hip hikers."

Dr Blount also discussed varieties of osteotomy of the hip and the use of internal fixation after osteotomy.

May 18–20, 1956. MINNEAPOLIS (Minnesota)

Visits were paid to the Gillette State Hospital for Crippled Children, Veterans' Administration Hospital, University Hospital and Shriners' Hospital.

Dr John H. Moe discussed scoliosis. He had operated on 400 of 800 cases seen since 1948, with no mortality. He considered seven to twelve the best age for fusion but was prepared to operate much earlier. He demonstrated his method of fusion, which is of the Hibbs type, the facets being grafted with iliac chips. He insists on meticulous haemostasis. Only autogenous iliac bone was used. As at Milwaukee, he advocated a little autogenous as opposed to massive homogenous grafting.

We attended the meeting of the Twin City Orthopaedic Club and were interested in the research projects being undertaken at the University. Dr Peltier discussed the experimental replacement of bone defects in dogs with commercial plaster-of-Paris and some of the problems of fat embolism.

We were fortunate to see a college football game, the spring practice of the University against the Alumni. To one brought up on rugby football the game was quite unintelligible. It was, however, a fascinating spectacle, though the protagonists appeared to have come from another planet. In addition to the game itself, brass bands, singing, cheering and the antics of the cheer leaders added to the enjoyment of faithful and enthusiastic supporters. I can now appreciate why cricket must appear extremely dull to our transatlantic colleagues.

From the air one could understand why Minnesota is called the State of Ten Thousand Lakes. The names are delightful—Minnesota (skyblue water), Minnehaha (laughing water) and Minnetonka (deep water) furnishing examples.

May 21–23, 1956. ROCHESTER (Minnesota)

The Mayo Clinic is fabulous—no other word can describe it. The original building with its tall tower stands out from afar and is matched in its size by the new building, in modern style, recently opened. The Clinic's facilities are superb and patients are drawn from all over the continent. All orthopaedic patients have, apart from special investigations, routine chest radiographs, a full blood count and urine analysis, while all other patients are routinely examined and fully investigated by the physicians before being transferred to the other special departments. It is interesting that here in the heart of America should be an example of a full-time salaried medical service.

The home of the late Dr W. J. Mayo—now Mayo Foundation House—is a " meeting place where men of medicine may exchange ideas for the good of mankind," and we were fortunate to dine in this house as guests of Dr Ralph K. Ghormley and his colleagues.

I doubt whether anywhere in the world are so many medical consultants gathered in so small an area. We enjoyed our short visit and were glad that we too had gone by the Mayos.

May 24–26, 1956. IOWA CITY (Iowa)

Meetings took place at Mercy Hospital and University Hospitals. We were delighted to meet Dr A. Steindler, who talked to us on some of the problems of low back pain. Though now retired from the Chair of Orthopaedics, Dr Steindler is still active in the consultative field and recently, in Mexico, delivered a five-day course of lectures in Spanish.

Dr Carol B. Larson was a fund of information and among many other things showed us some excellent results of cup arthroplasty, while Dr I. V. Ponseti discussed slipped epiphysis, Legg-Perthes' disease and scoliosis, and introduced us to the active ingredients of the wild flowering sweet pea.

We were fortunate to be able to join in the meeting of the Mid-West Orthopaedic Club.

Iowa City is a real University town as we understand it in Britain and, thus, has enormous intrinsic charm.

May 27, 1956. CHICAGO (Illinois)

Our stay in Chicago was very brief, but in this short time we were made to feel very much at home by Dr E. L. Compere and Dr J. J. Fahey. Time permitted no more than a rapid sightseeing tour of the Universities, Hospitals and City.

May 28–June 3, 1956. LOS ANGELES (California)

We visited the University of California Medical School, Rancho Los Amigos Hospital, Los Angeles County Hospital, Children's Hospital and Los Angeles Orthopaedic Hospital. At each of these centres excellent programmes had been arranged.

At the University of California Medical School prosthetic problems were discussed. An enormous amount of research, in conjunction with the Engineering Faculty, is being devoted to the problems of the upper limb amputee.

Under the direction of Dr Vernon P. Thompson, Rancho Los Amigos Hospital, Hondo, has been developed as a centre for respiratory poliomyelitis, and is the largest of fifteen such centres. We were impressed with the number of operations that had been performed on patients with very low vital capacities and on patients who relied on some form of positive-pressure breathing. When vital capacities were below 30 per cent elective tracheotomy was invariably performed before surgery. In 1955–56, 164 operations were performed on such patients, thirty-nine of whom had vital capacities below 30 per cent. There had been no operative mortality. These figures speak for themselves. It was fascinating to see all forms of therapy, including pool treatment, being carried out with positive-pressure breathing, with or without tracheotomy. Again, we met with enthusiasm for abdominal fascial transplants in the severely paralysed.

Dr J. C. Risser discussed scoliosis with us and demonstrated his latest model of the double

localiser frame. He seldom uses the turnbuckle cast now. Dr Risser favours the Hibbs type of spine fusion without any bone grafting, but with meticulous attention to facet fusion. He emphasised the folly of massive posterior bone grafting. We gained the impression that his operative rate was high, on the assumption that any curve with growth left in it was likely to increase. He delighted us with so many characteristic aphorisms that I cannot refrain from quoting—and I hope not misquoting—a few: " Braces do not control an increasing deformity." " A theory which does not lead to therapy is useless." " A curve which is present must have got worse." " Leaving facets in a fusion is fallacious."

Dr C. L. Lowman discussed abdominal fascial transplants, showed a good film of the operation, and presented some beautiful cases. He was talking to a group partly converted by what they had already seen elsewhere, and the conversion was complete. There appears to be a very real place for such transplants in selected cases, if too much is not expected from them.

Dr J. Vernon Luck interested us in conservative operations on Dupuytren's contracture. Based on the pathology of this condition he advocated enucleation of the nodule in the proliferative stage, subcutaneous fasciotomies together with local excision of the nodule in the involutionary stage, and fasciotomies alone in the burnt-out stage when the nodule had disappeared. The interphalangeal joint nodules often involved the capsule and these required early operation. Open fasciotomy was safest in the fingers.

Dr J. H. Boyes demonstrated some interesting tendon transplants. For central slip injuries of the extensor tendons he advocated splinting of the proximal interphalangeal joint in full extension and active use of the distal joint to stretch the lateral expansions.

We enjoyed a visit to the 20th Century Fox studio in Hollywood and spent an extremely pleasant Memorial Day visiting the Dos Pueblos Orchid Factory and Santa Barbara Mission.

June 4–10, 1956. SAN FRANCISCO (California)

All we had been told about the beauty of San Francisco prepared us for disillusion, but San Francisco more than lived up to its reputation. My only regret was that Sir Francis Drake should have missed the narrow Golden Gateway to this wonderful harbour and dropped anchor fifty miles farther up the coast.

Dr LeRoy C. Abbott discussed the function of the clavicle. He considered it a redundant bone and had never seen any trouble from its removal. He showed an excellent animated film of the anatomy of this region.

We spent an interesting day with Dr Sterling Bunnell and Dr L. D. Howard, watching several operations and discussing hand problems.

Dr V. T. Inman presented some of his current biomechanical research. This research was initiated in an endeavour to solve some of the fundamental problems involved in lower limb prostheses. Whereas research into upper limb prostheses is conducted at the University in Los Angeles, research into lower limb prostheses is being carried out in Berkeley. We did not feel, however, that Roehampton was in any way behind in general advance in prosthetic problems.

Dr F. C. Bost conducted us on a most enjoyable and profitable ward round at Shriners' Hospital. The Shriners' Hospitals for Children were amongst the best we saw in America. It is interesting that a sixty-bed Children's Hospital is found to be the most economical and efficient unit and all the Shriners' Hospitals we visited conformed approximately to this figure.

Dr E. R. Schottstaedt showed us some examples of functional arm bracing for the virtually completely paralysed upper extremity, where reconstructive surgery was not a practical proposition.

In addition to sampling much of San Francisco's charm, we spent a most enjoyable day visiting the Korbel and Krug Wineries with a barbecue lunch in the renowned Bohemian Grove.

June 11, 1956. PORTLAND (Oregon)

During a very brief visit we spent a valuable morning at Shriners' Hospital with Dr Leo Lucas and his team. In between discussion on many subjects, which included an interesting paper by Dr W. Snell on gout, we were shown the relevant stages of three different osteotomies, each in as many minutes: M osteotomy for tibial version, oblique " notched " osteotomy for metatarsus primus varus, and lateral displacement osteotomy of the calcaneum for varus heel in recurrent club foot.

June 12–14, 1956. SEATTLE (Washington)

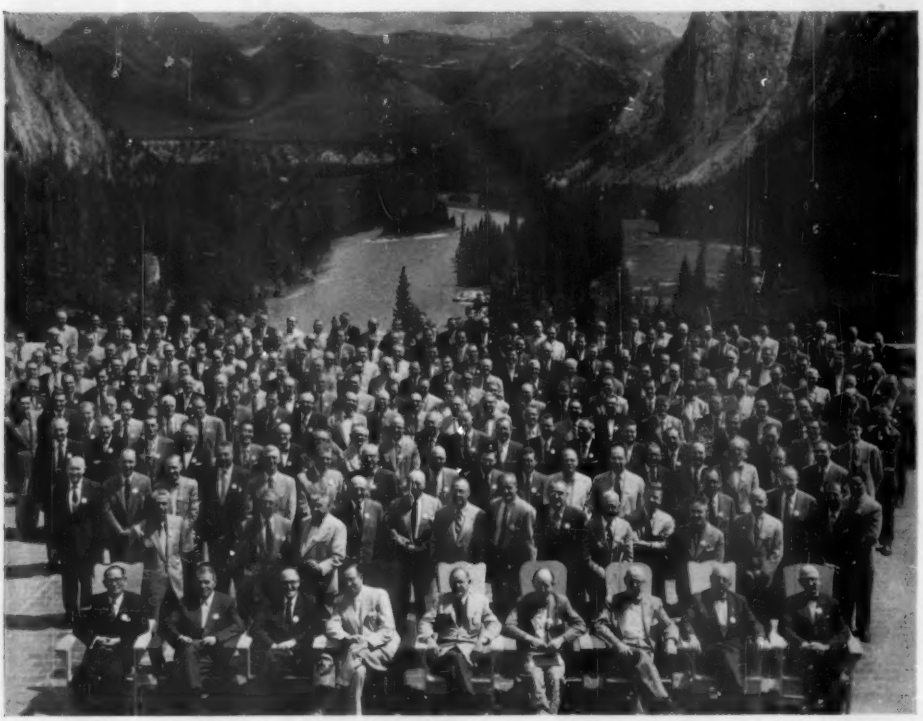
As guests of the Puget Sound Chapter of the Western Orthopaedic Association, we attended sessions at the Children's Hospital, Swedish Hospital, Veterans' Administration Hospital, and Health Sciences Building, University of Washington.

We were interested in the radioisotope studies of bone metabolism presented by Dr Robert D. Ray and Dr Göran Bauer, and were confounded by the working of an electronic analogue computer. Dr Ray also gave a fascinating talk on his experimental studies of bone grafts and bone replacement.

Among many short presentations, Dr Roger Anderson showed that internal or external metallic fixation could be used in the treatment of almost any fracture. Throughout our tour we were perhaps more critical of the operative treatment of fractures than of anything else we saw. But it became apparent that often this method of treatment was dictated not so much by the intrinsic nature of the fracture as by economic, social and other reasons. Though we saw many satisfactory results from open reduction and internal fixation of lower limb fractures, we were more than ever convinced that, whenever possible, conservative treatment with an intact skin was the method of choice.

June 15, 1956. VANCOUVER (British Columbia)

A morning session was spent at the Vancouver General Hospital. Dr H. H. Boucher, President of the Canadian Orthopaedic Association, described his method of lumbo-sacral fusion. This



American Orthopaedic Association meeting, Banff Springs, Alberta.

comprised oblique screw fixation of lamina to root of pedicle across the facet, interlocking of bone flaps from L.5 and S.1, and packing with bone chips from the posterior iliac region. His patients were up on the third day and home on the tenth day without any support. Exercises were started three months after operation. In 150 patients so treated, he was unaware of any failure of fusion. Six patients were shown who certainly bore this out.

June 16, 1956. EDMONTON (Alberta)

The Canadian Orthopaedic Association Meetings are preceded by a Clinical Day at a centre within reach of the main meeting place. Edmonton was the choice this year. At the University Hospital many interesting short papers were read and clinical cases presented by orthopaedic surgeons from Edmonton and Calgary.

On our journey we had now travelled from New York on the east coast, through the Middle West, across to and up the whole length of the west coast into Canada. So to the climax of our tour—the meetings of the Canadian and the American Orthopaedic Associations at Jasper and Banff in the heart of the Canadian Rockies.

June 17–20, 1956. CANADIAN ORTHOPAEDIC ASSOCIATION—Twelfth Annual Meeting. Jasper Park Lodge, Jasper, Alberta.

June 20–23, 1956. AMERICAN ORTHOPAEDIC ASSOCIATION—Sixty-ninth Annual Session. Banff Springs Hotel, Banff, Alberta.

Reports on the scientific aspects of these excellent meetings will doubtless be recorded in other numbers of this Journal. I do not, therefore, intend to comment on them but would endeavour to set the scene.

Jasper (3,472 feet) and Banff (4,538 feet) are 185 miles apart in the great National Parks of Alberta. Both lie in lovely wooded valleys, which are coursed by rushing, tumbling streams and are surrounded by peaceful, deep blue lakes. The snow-capped Rocky Mountain ranges, which are majestic in their grandeur, tower up to 6,000 feet above them. The setting is really magnificent.

I should remember Jasper if only for a wonderful day's trip to Maligne Lake. There was also a memorable fishing contest between Dr Earl D. McBride and Dr J. Edouard Samson, a fantastic round of golf with a vital putt watched by two large black bears from an overhanging tree, and a superb barbecue by the edge of a lovely lake followed by square dancing. These are but a few examples of a truly Western Occasion and it may be mentioned that everyone attending the Canadian Meeting was presented with a white " ten-gallon " hat.

Among many memories of Banff, I shall recall a journey by chair lift to the top of Mount Norquay, my relief that the downward journey was equally simple and not on ski, and a delightful, profitless afternoon's fishing in one of the nearby lakes. The greatest pleasure in Banff, however, was to join again so many of our earlier American hosts and to meet other members of the Association for the first time. It was great fun, on more than one occasion, to be able to introduce an American to a Canadian, or even an American to an American.

From Banff to Calgary and thence by air to New York, where we embarked in the " Queen Elizabeth " on June 27, 1956. After five calm and uneventful days we docked at Southampton on July 2 having completed a round trip of some 14,000 miles. So ended a memorable visit to the North American continent.

Was this type of tour, where we visited many centres with but a few days at each, as valuable as one spending longer in fewer places? We were unanimous that our tour could not have been improved and that its main value lay in the number of centres visited and orthopaedic surgeons met. Only thus was it possible to gain a cross-sectional impression of another country's surgery. We felt that in a few days of well-prepared intensive work and endless frank discussion we were able to gain a very good idea of the scope and mode of thought of the various orthopaedic centres visited.

Meeting so many orthopaedic surgeons has broadened our orthopaedic vision and I am sure our general vision too. Our American and Canadian colleagues are now personalities and friends and not merely names. We know something of the centres in which they work and we shall, therefore, read their publications with greater interest and understanding.

But more than this, we have discovered that beneath our superficial differences we are very much the same. Our problems are similar, we certainly have the same difficulties and on the whole our approach to these problems is along parallel lines.

We are extremely grateful to the British Orthopaedic Association who sent us.

We offer our heartfelt thanks to the American and Canadian Orthopaedic Associations who invited us and to members of the American Academy of Orthopaedic Surgeons, members of Regional Orthopaedic Clubs and to many young orthopaedic surgeons, as yet belonging to none of these, who helped to make our visit so profitable and enjoyable. For their generosity, kindness and hospitality we shall ever be in debt.

DAVID L. EVANS.

SCIENTIFIC SOCIETIES AND REGIONAL ORTHOPAEDIC CLUBS

THE BONE AND TOOTH SOCIETY

The Bone and Tooth Society held a symposium on bone tumours at the Institute of Orthopaedics, London, on March 27, 1956, with Professor D. H. Collins in the Chair.

A classification of bone tumours—*Dr A. D. Thomson* presented a classification based on the method adopted by Lichtenstein (1952) and related the tumours that might arise from the primary tissue elements normally present in bone. Tumours might arise to give specific and recognisable histological pictures from bone tissue, cartilage, fibrous tissue, fat, blood vessels, osteoclasts and marrow cells. In this simple bone classification the malignant tumours were separated from the benign, and the

prognostic patterns of the malignant tumours were discussed. It was found that the histological subdivisions of the various tumour entities reflected to a large extent the prognosis of any given tumour group and this fact alone justified the histological segregation of the various tumours arising in bone.

Primary osteogenic tumours of the skeleton and their relationship to bone growth and metabolism—*Dr C. H. G. Price* described osteochondroma and osteogenic sarcoma, the two commonest primary bone-forming skeletal tumours. The analysis of a series of each of these two tumours indicated certain similar features: 1) anatomical distribution; 2) common metaphysial site of origin in any given bone; 3) age incidence; 4) predominance in the male; 5) chronological age incidence. These points were correlated with the known differences in the pattern of skeletal development in the two sexes. The mode of growth of a solitary benign osteochondroma could be shown to be reproduced, albeit with gross distortion, in the more slowly growing forms of osteogenic sarcoma. The bearing of this upon the stromal differentiation of osteogenic sarcoma in relation to age of the patient was indicated.

Experimental bone tumours—*Dr H. A. Sissons*, reviewing work on bone tumours in experimental animals, said that in many problems, such as histogenesis and causation, only a tentative answer could be given from a study of human bone tumours, but experimental studies contributed important information. Spontaneous bone tumours in other species had received quite detailed study, particularly in dogs and mice. They did not appear to have been observed in rabbits. Special strains of mice—such as that of Pybus and Miller, in Newcastle—had been developed by selective breeding, with a very high incidence of bone tumours, suggesting, in this species at least, an important genetic background. Transplantation of animal bone tumours had shown that the production of bone by the tumour cells might persist for many generations of transplant. It usually ceased eventually, however, and other permanent changes occurred in the tumour: its growth rate often increased, and it was found to grow in a wider range of strains of animal than originally. These facts suggested changes in the genetic constitution of the tumour, and might parallel certain changes that occurred in the behaviour of individual human bone tumours during the course of their clinical development. In the field of carcinogenesis, Dr Sissons discussed a number of contrasting causative agents, including ionising radiations and radioactive materials localising in the skeleton, carcinogenic hydrocarbons, and beryllium and its compounds. He hoped that the study of the earliest stages of tumour formation, which is possible only under this type of experimental condition, would throw light on the histogenesis of bone tumours.

SOUTH-EAST METROPOLITAN REGION ORTHOPAEDIC CLUB

The Club met at the Kent and Canterbury Hospital, Canterbury, on July 14, 1956. Cases were shown by Mr F. G. St Clair Strange and Mr M. L. Mason.

A series of cases of muscular dystrophy and other neurological disorders produced the reminder from Mr Strange that these disorders must be remembered when examining apparently simple cases. Notably in the foot disorders of childhood, such as pes cavus, it was always wise to examine for the neuromuscular diseases, which might first manifest themselves in this way.

Miscellaneous cases—Two cases of juvenile osteochondritis of the capitulum following relatively minor injuries were shown by *Mr M. L. Mason*, together with a case of post-traumatic deformity of the head of the radius in a boy of twelve. Though function was good at present, a discussion took place on the dangers of excising the radial head during the growing period. Mr Mason had some experience of this without subsequent deformity at the wrist; but *Sir Max Page* and *Mr H. L.-C. Wood* emphasised the risk involved, and Sir Max believed that the radial head should be conserved in young people, even though it appeared to be grossly damaged at the time of injury.

Mr Mason also showed two patients with spastic torticollis treated by total excision of the sternomastoid muscle on the affected side. He had done this operation four times, and in all cases the results had been encouraging. Of the two patients demonstrated one was completely satisfactory but the other still had some degree of spastic torticollis with involuntary movements.

Mr F. G. St C. Strange showed a case of refracture of a patella which had been fractured and sutured with silver wire in 1914. At operation fragments of silver wire were found scattered about the joint, some projecting into it. The whole lining surface of the joint, including the synovial membrane, the articular cartilages and the semilunar cartilages, was stained black by diffuse silver impregnation but there was extraordinarily little evidence of arthritic change or other reaction.

Among the many other patients shown were four with tuberculosis of the hip or knee who had recovered an excellent range of movements. One boy with hip disease treated by synovectomy and curettage of a cavity in the acetabular roof, coupled with antituberculous drugs and two years'

splintage, had regained an almost full range of hip movement. A girl with tuberculous disease of the hip treated conservatively, and two patients with tuberculosis of the knee proved by biopsy, but not otherwise operated upon, had also regained excellent movements after about nine months' immobilisation and drug therapy.

The demonstration of cases was so generous that many members could not do justice to an excellent demonstration of radiographs of bone tumours also arranged by Mr Strange.

NORTH-WEST METROPOLITAN ORTHOPAEDIC CLUB

The first meeting of the recently formed North-West Metropolitan Orthopaedic Club was held at Heatherwood Orthopaedic Hospital, Ascot, on May 12, 1956. The following members were present: Mr G. P. Arden, Mr F. G. Ward, Mr W. E. Tucker, Mr D. Walker, Mr G. S. Storrs, Mr W. Arclay Steel, Mr R. H. Maudsley, Dr R. T. Ahern, Mr P. R. N. Kerr, Mr G. H. Pearce, Mr W. Herschell, S./Ldr. J. S. Winter, Gp./Capt. L. Crooks, Mr W. Waldie, Mr D. Rowlands, Mr J. R. Elder, Dr D. J. Roebuck. The guest speaker was Mr J. C. Scott of Oxford. Mr G. P. Arden was elected secretary. At the clinical meeting cases were shown.

Tuberculosis of spine—*Dr R. T. Ahern* showed a patient with old-standing tuberculosis of the thoraco-lumbar spine with persistent sinuses in both groins for eight years. A sinograph showed opaque fluid extending up both psoas sheaths into a cavity in the spine. The cavity was approached posteriorly, curetted, and packed with autogenous bone chips under antibiotic cover which was continued for two months. The sinuses healed within a week of operation and have remained healed for eight months.

Tuberculosis of neck of femur—*Dr Ahern* showed a child with an endosteal tuberculous focus in the left femoral neck, with extensive cavitation involving the lower part of the capital epiphysis. Combined conservative treatment and antibiotics had been unsuccessful. Through a lateral approach through the femoral shaft, sequestrectomy was performed and one gramme of streptomycin was applied locally. Antibiotics were continued for two months. Radiographs at three months showed complete resolution of the focus and clinically full movement of the hip joint was present. Three and a half years later the child is entirely normal.

Multiple tuberculous foci—*Dr Ahern* showed a boy of eight who six years before had had miliary tuberculosis and tuberculous meningitis and had made a complete recovery with six months' treatment with streptomycin. He developed synovial tuberculosis of the left hip three years later and again made a complete recovery with a year's conservative treatment and three months' streptomycin. He was later admitted with an irritable right hip. Radiographs showed early destructive changes in the femoral neck, and a month later the destruction was much more marked. A large cavity was entered and emptied through a Smith-Petersen approach. Streptomycin was applied locally. After a further three months in a plaster spica with systemic chemotherapy the lesion healed and the cavity was obliterated. A year and a half later the hip was normal.

Chondromyxosarcoma—*Mr G. P. Arden* showed a case of chondromyxosarcoma of the right lower femur in a girl of seventeen years, with an arteriograph. Amputation had been carried out through the mid-thigh four years and two months ago and the patient is still alive and well. He also showed a case of paralytic dislocation of the hip in a child of two years with poliomyelitis treated by adduction osteotomy, and a congenital dislocation of the hip treated by reduction on a frame and then derotation osteotomy.

Monteggia fracture—*Mr W. Herschell* showed a case of Monteggia fracture of the extension type, which was stable only after reduction in extension. The ulna became angulated in plaster; so operative correction and fixation with a Rush nail was undertaken. Early movement was allowed.

Congenital coxa vara—*Mr Herschell* showed a child of nine years treated by modified Brackett osteotomy with pin and plate fixation.

Pes valgus—*Mr R. H. Maudsley* showed a case of gross pes valgus for which calipers had been required in a boy aged nine years. An extra-articular subtalar arthrodesis (Grice) had been performed on both feet with complete correction, enabling him to dispense with the calipers.

Traction apparatus—*Mr Maudsley* showed prototypes of a new system of overhead beams for traction and suspension. In the beams were fitted spiral balances which exerted a constant tension throughout their travel, and replaced normal weights and pulleys. The balances were readily adjustable.

Pathological fractures—*Mr F. G. Ward* showed a woman of forty-six who had been treated by radiotherapy thirteen years before for a soft-tissue sarcoma involving the right greater trochanter.

Subsequently she sustained four fractures of the femur, the last being in 1950. Radiographs showed marked sclerosis and a " fatigue " type of fracture. The fracture was realigned with about an inch of shortening and fixed with a nail plate, and iliac chips were packed about the bone. Four years later the bone quality had been restored almost to normal.

Fractures of femoral shaft—After the clinical meeting *Mr J. C. Scott* gave a talk on the treatment of femoral shaft fractures, reviewing a series of a hundred cases in adults in which the method of treatment had been mostly conservative. Those in which reduction had been difficult or unstable had been treated by an Egger plate and traction.

SOUTH-WEST ORTHOPAEDIC CLUB

The spring meeting of the South-West Orthopaedic Club was held at the Mount Gold Hospital, Plymouth, on June 2, 1956. The chairman was Mr M. H. Salz.

Tumours of the pelvic wall—*Mr Norman Capener* discussed the tumours of the pelvic wall that he had treated during the last twenty-five years. He said that cartilaginous elements of the developing innominate bone were considerable and it was not surprising that chondromata occurred relatively frequently. He showed two patients in whom large tumours of the ilium had been successfully removed and who walked well. It was possible to remove large pieces of iliac bone without resultant disability if the muscle layers were reconstituted carefully. Such radical excisions were preferable to hindquarter amputation.

Surgical treatment of hydrocephalus—*Mr P. Childs* reported the results of seven cases of hydrocephalus treated by establishing peritoneal drainage of the subarachnoid space by means of polythene tubing—an operation conceived by Spitz of Philadelphia. There had been five survivals. The operation had been performed when there was evidence of progressive enlargement of the cranium and when it was clear that there was a communicating hydrocephalus. The first operation was performed three years ago. It was too early to say how satisfactory the operation would be, but so far the results had been encouraging in that the increase in the size of the skull had been retarded.

Acute osteomyelitis—*Mr M. H. Salz* reviewed 101 cases of acute haematogenous osteomyelitis treated at Mount Gold Hospital during the last ten years. There were fifty-nine males and forty-two females. The highest age incidence was between eleven and thirteen. The tibia and femur were the commonest sites and together formed 65 per cent of all cases. Staphylococcus aureus was cultured in seventy-two cases, and was penicillin-sensitive except in fifteen cases. Penicillin was used in all but the resistant fifteen cases, and 1,000,000 units were given daily in four-hourly doses for three weeks. There was one case of penicillin allergy. The blood sedimentation rate was used to indicate activity of bone infection. Operation was undertaken in ninety cases. It consisted in bone drilling and loose primary suture. There were seventy-three good results with no complications and with ultimate return to normal activity. There were seven bad cases all of which had loss of joint function. Two-thirds of all patients were admitted during the first four days. All the poor results occurred in those who did not reach hospital until five or more days after the onset of the illness. There was no death in the series. The points brought out by the analysis were the importance of early diagnosis and the value of large doses of antibiotics with early surgery and decompression of the bone by drilling.

Osteoid osteoma—*Mr F. T. Wheeldon* reviewed the literature and clinical description of the condition and reported three personal cases: 1) A twelve years old schoolboy with a lesion in the body of the lateral cuneiform of the right tarsus; 2) two patients with lesions in the mid-shaft of the femur both causing pain around the knee. The second of these was a man of thirty-five who suffered severe pain for two and a half years and was examined by many consultants, all of whom considered him to be psycho-neurotic until final diagnosis and surgical excision brought complete relief.

Treatment of acute bulbar palsy—*Dr D. F. Johnstone* outlined the treatment of acute bulbar palsy. There were two main types: 1) With paralysis of the pharynx and the palate; and 2) with paralysis of the respiratory centre as well. The pharyngeal type was recognised by inability to swallow and regurgitation of food. When the respiratory centres were involved there was weakening of the respiratory process; this was frequently accompanied by hyperpyrexia, facial weakness and nystagmus. He regarded vomiting as an important premonitory sign in poliomyelitis, as it indicated that respiratory involvement would soon occur. Active intervention should consist of preventing the patient from inhaling secretions and vomit and of artificial respiration. In the first type, postural treatment was dramatic. The patient should be nursed in the semi-prone position with a 10–15 degrees' tilt. Mechanical suction was carried out and nasal feeding was used. Usually the patients improved rapidly. When the respiratory centres were involved, the patient was usually delirious or comatose and there might be pulmonary collapse. Treatment of this was more difficult. It was essential to have

the assistance of a competent anaesthetist and artificial respiration should be carried out as soon as possible. The patient was intubated using a short-acting curare compound or hexobarbitone; later a tracheotomy was performed as this was more satisfactory. An endotracheal tube could not be left in position for long on account of the danger of causing ulceration of the trachea. The apparatus for artificial respiration which he preferred to use was the Ritchie Russell positive-pressure machine. The tracheotomy tube that he employed had a side opening with an inflatable latex rubber cuff. The cuff had to be replaced every twenty-four hours as it wore out at the end of this time. Continuous suction was necessary during the first twenty-four hours as secretions usually increased during this period. Continuing hyperpyrexia after adequate control of respiration was likely to be an indication of a fatal outcome.

Other cases—*Mr G. J. Lillie* presented two cases: 1) A man of forty with osteomyelitis affecting the third cervical vertebra and paraplegia; and 2) a case of arthrogryposis in a boy aged six who had been under treatment since birth. *Mr H. J. Hambury* reviewed the treatment of mallet finger and reported the results of treatment in twenty-six cases in which a metal finger splint was used. There had been only three unsuccessful results. The splint was retained for an average of seven and a half weeks. The result was not always perfect and there was sometimes a slight extension lag. *Mr M. H. Salz* reported two cases of carcinoma of the pancreas with secondary bone deposits.

Cerebral palsy—In the afternoon a visit was paid to the Dame Hannah Rogers School for Cerebral Palsy at Ivybridge. Mr Norman Capener, chairman of the governing body, said that the Institution was fundamentally an educational foundation and not a hospital. At present there were twenty-five pupils but soon the school would be enlarged to accommodate fifty. While not belittling the benefit that resulted from physiotherapy he felt that the school's chief value lay in giving the child with cerebral palsy an educational and social background which would make it a more normal citizen. The cost of maintenance for each child annually was about £550. Such a school could only be justified by the advances it could make, based upon careful research.

Mr G. J. Lillie outlined the principles of treatment. At present physiotherapy followed the Bobarth methods. Surgery had little place except for the purpose of salvage. The only operations which might be helpful were subtalar and midtarsal arthrodesis, and transplantation of the hamstring muscles into the femoral condyles when there was marked flexion deformity of the knee. Treatment was concerned with establishing normal balance and righting reflexes and the prevention of deformity.

Dr H. Jolly discussed the diagnosis of cerebral palsy, in which the history was important. Fits and jaundice were significant. In examination there were two aims, first to detect lack of progression of development and then to detect abnormal reactions and the perversions of reflexes. It was essential to know the age at which reflexes disappeared, as failure to mature at the correct rate was a helpful diagnostic point. The normal child would suck and swallow at birth. Persistent dribbling was abnormal. The normal child smiled at four to six weeks. The mentally deficient child usually smiled earlier. The head was supported by the normal child at three months when the child pulled up from the recumbent position. In a case of cerebral palsy it fell back. The grasp reflex disappeared at the age of three months but continued for a long time in cerebral palsy or in the backward child. Persistent flexion of the thumb was often found when there was mental deficiency. Some reflexes that were normal at first might persist beyond the normal stage and be exaggerated—for instance the tonic neck reflexes which might continue for a long time and dominate the whole life of the child. The true spastic usually progressed through three stages: 1) initial hypotonia lasting for six months or more when there was poverty of movement; 2) a dystonic phase in which there were shooting movements with no reflexes; 3) the stage of true spasticity. In athetoid cases the stage of hypotonia was of longer duration and it was two to five years before the condition was recognised. The earliest sign was athetoid movements of the head and neck.

A demonstration of the methods of treatment was given by the physiotherapy staff and the speech therapist.

NEW ZEALAND

NEW ZEALAND ORTHOPAEDIC ASSOCIATION: 1956 MEETING

The Annual Meeting of the New Zealand Orthopaedic Association was held at Dunedin Hospital on May 16–18, 1956, under the chairmanship of the president, Mr Morris Axford (Auckland). The following were elected to office: president, Mr H. Walden Fitzgerald (Dunedin); vice-president, Mr Allan Macdonald (Auckland); hon. secretary-treasurer, Mr Alan Alldred (Dunedin); editorial secretary, Mr N. W. Nisbet (Dunedin).

Recent advances in British orthopaedics—*Mr N. W. Nisbet* (Dunedin) spoke of the work he had seen during his period of study leave in Britain, during which he was appointed Lord Nuffield research scholar at the Nuffield Orthopaedic Centre, Oxford, for 1955, under Professor J. Trueta. Particular mention was made of the methods used to study the blood supply of bone, especially of the femoral head. These were also applicable to the soft tissues and were used to study the degeneration and regeneration of tendon. Recent advances in the treatment of congenital dislocation of the hip, of bone and joint tuberculosis, and of scoliosis, were also described.

Carpal tunnel syndrome—*Mr Rex Blunden* (Christchurch) said that in addition to those cases due to spontaneous compression of the median nerve on bony lesions in the carpus, there were those associated with disease of the tendon sheaths. Such cases presented swelling of the fingers accompanied by numbness and tingling. He illustrated two cases. He recommended a more extensive exposure of the tendons than was required to divide the carpal ligament, in order to excise the sheath.

Pathological dislocation of the atlas—*Mr J. R. Kirker* (Auckland) described the case of a middle-aged woman who had injections of hydrocortisone into the cervical region to relieve tha pain and stiffness associated with degenerative changes in the cervical spine. She developed repeated retropharangeal abscesses and after the drainage of one of these complained of severe pain in the upper neck, and of occipital headaches. Radiographs showed a pathological dislocation of the atlanto-axial joint. After a period of skull traction the dislocation was reduced and the patient recovered. In the discussion which followed the danger of the empirical use of hydrocortisone was stressed.

Spondylolisthesis with intact pedicles—*Mr R. H. Dawson* (Palmerston North) described the case of a girl aged thirteen who complained of pain in the right buttock after a minor fall. Examination revealed lumbo-sacral tenderness and restricted flexion of the spine. Radiography showed lumbo-sacral spondylolisthesis with no defect in the pars interarticularis. The facets of the posterior interarticular joints were in the sagittal plane. Because of increasing symptoms the spine was stabilised by bone grafting and after thirteen months the patient had made a good recovery.

Review of autogenous and homologous bone grafts—*Mr W. Parke* (Gisborne), whose paper was read by Mr Harman Smith (Auckland), had reviewed all his cases of bone grafting between 1949 and 1953 to compare the results of autogenous and homologous grafts. In his series the homologous grafts were preserved by deep freezing. Of twenty-four autogenous grafts seven were classified as failures. This was too small a series to produce statistical results but Mr Parke thought that autogenous bone, containing living cells, should be used for technically difficult grafting operations and refrigerated bone reserved for the easier types of grafting. *Mr Alexander Gillies* (Wellington) said that Mr Parke was extremely critical in assessing his results. Some he would not have classified as failures and said that if these were included the results were comparable to those in other series.

Vascular pattern in bone as an aid to the diagnosis of bone tumours—*Dr A. C. Begg* (Dunedin), introduced by Mr Morris Axford, said that a study of the vascular pattern of suspected bone tumours was found to provide both positive and negative information of value in diagnosis and treatment. In the arteriograph of a normal limb no arteries could be seen to enter the periosteum. When, however, contrast medium was injected into a bone the deep and superficial veins were flooded with a concentration of medium far greater than that which occurred after injecting the venous system. This showed the great vascularity of living bone, which appeared to be a sponge through which a great volume of blood was rapidly circulating. It was supplied by minute periosteal vessels, most numerous in the region of the epiphyses. The nutrient artery took little part in its nourishment and might be regarded as a vestigial structure indicating the situation of the foetal diaphysis and the most avascular region of the adult bone. Arteriography was carried out quickly and easily under local anaesthesia, and by selecting the appropriate vessel the vascular pattern of most bone tumours was demonstrable. The application of a tourniquet immediately distal to the lesion for a short period during the injection was helpful. A 35 per cent solution of Uriodine was satisfactory except in the aorta, where a 70 per cent solution was required. The blood supply of malignant tumours of bone was increased. The appearance of visible arteries to periosteum, and of large abnormal vessels of increasing diameter and tortuosity, was most suggestive. A rapid circulation through the tumour was often demonstrated.

The additional information was most helpful in doubtful cases and had permitted a more certain diagnosis. In osteosarcoma arteriography gave such striking evidence of malignancy that the need for biopsy was overcome in some cases.

Results of intervertebral bony fusion—*Mr N. W. Nisbet* (Dunedin) and *Mr Anthony James* (Dunedin) reviewed the results in nineteen cases of intervertebral bony fusion. Eight out of ten patients with intervertebral disc lesions or their sequelae were cured of pain but two results were poor. Only two

patients showed radiological evidence of fusion. Six out of nine patients with spondylolisthesis were cured of pain but three results were poor. Six showed radiological evidence of bony fusion but included two of the poor results. Overall fourteen out of nineteen cases were cured, and five were unrelieved although some of the patients were working; eight fused by bone and eleven were pseudarthroses. Relief of symptoms in the presence of pseudarthrosis, and failure to relieve symptoms in the presence of bony fusion, were discussed. Complete freedom from symptoms did not occur for several months after operation in most cases.

Malignant schwannoma—*Mr Kennedy Elliott* (Wellington) reported the case of a boy of fourteen who complained of pain in the left foot, sciatic paraesthesia and weakness of the left leg. Examination revealed a partial sciatic paralysis and a series of globular swellings along the sciatic nerve. At operation a series of tumours within the nerve sheath were found. Biopsy revealed a malignant schwannoma spreading centrally up the nerve. Because the upward extension was not known the abdomen was opened but no intrapelvic mass could be felt. The sciatic nerve was resected up to the sciatic notch. The pathology of the condition was briefly discussed.

Book Reviews

POTT'S PARAPLEGIA. By D. Ll. GRIFFITHS, University Department of Orthopaedic Surgery, Manchester Royal Infirmary; Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry; H. J. SEDDON, Institute of Orthopaedics, University of London and Royal National Orthopaedic Hospital, London; and R. ROAF, Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry; Department of Orthopaedics, University of Liverpool. 10×7 in. Pp. xiv+129, with 26 figures, 30 plates and 32 tables. Index. 1956. Oxford University Press. London: Cumberlege. Price 50s.

This is a notable monograph. Though the word is not customary for a work produced by more than one author it is, nevertheless, concerned with one narrow though important field of a large subject. Furthermore it is a splendid example of critical and exhaustive discussion in the best tradition of monograph writing. The authors and their publishers are to be congratulated upon their enterprise in these times of economic stress. One's hope is that this may be the first of a considerable series of British orthopaedic monographs produced, as this obviously has been, as a labour of love and creative zeal. The attraction of this work is not least in its literary style. It is a pleasure to read in spite of the necessary accompaniment of statistical detail: charts, diagrams and graphs.

It would be invidious to single out one author as the germinal spirit behind the work though it is a pleasant game to pick out the parts which show the characters of each. Nevertheless the work clearly reflects the great influence which Seddon has exerted upon the modern understanding of the subject and follows the great French tradition of which he is clearly a disciple. To him we owe the concept of attacking from in front the cause of spinal cord compression. The rest of us have been mere technicians.

The book comprises twelve chapters. The first is short and introductory, but emphasises that though tuberculosis has receded in many countries it still is a great scourge, particularly in some tropical communities. It is therefore still of the greatest importance that knowledge should be disseminated upon the clinical and pathological features of Pott's paraplegia and that, in general, decompression is the most effective treatment. In the next chapter the clinical features are discussed beginning with statistical data which, while noting the well known dominant incidence of spinal disease in the first five years of life and the move to the older ages for the incidence of paraplegia, nevertheless does draw attention to the surprising figure of 23 per cent of cases of paraplegia in which paraplegia was the presenting symptom. While finding it difficult under modern conditions to accept the diagnostic and prognostic distinctions between paraplegia of early and late onset, the authors find that " in spite of the irritating vagueness of the line of demarcation " these distinctions " cannot be wholly ignored." Facts relating to duration of paralysis, occasional spontaneous recovery, recurrent paraplegia, mortality and clinical types are carefully marshalled to support the main theme of the later part of the book. This section includes some illuminating charts by Mr B. M. Hay which amongst other things note the presence of sensory disturbance, a matter strangely omitted from the rather scant neurological discussion. The latter deserves fuller treatment, because, while there may be no distinctive neurological features in Pott's paraplegia, the neurological pictures are many and varied and merit elucidation.

Chapter III upon Pathology opens with a valuable historical record and gives to J. P. David the credit for the first accurate description of the disease in the same year as Pott's classic paper appeared. The pathological studies are based upon evidence obtained at operation or autopsy upon eighty-six out of 175 cases that were dealt with in the clinical discussion. The inflammatory and purely mechanical causes of paraplegia are given. Abscess is still recognised as important in nearly half the cases of early paraplegia. Among the other inflammatory causes of granuloma and caseous material is infective thrombosis, though no further case has apparently been described since Seddon's paper in 1935. This is interesting because the possibility of this occurrence would have appeared greater.

In the discussion of mechanical factors we have the really important material supporting anterior decompression. There is an interesting discussion of inflexion of the spine when the cord is stretched across a sharp body ridge, and the extraordinary way in which, in many cases, the cord escapes harm. One factor in severe deformity that they have not mentioned is the effect of the severe compensatory lordoses which appear above and below the kyphos: particularly the former because cervical lordosis may greatly accentuate the bow string effect by which the cord is stretched across the anterior bony ridge especially in lesions of the upper thoracic spine. This may partly explain " how paraplegia

develops when the spine is healed and is mechanically stable." This is a most valuable chapter, and so is the next, on prognosis, which disposes of the sharp distinction made by Sorrel-Déjerine between the prognosis in early paraplegia and that coming on later (36 per cent and 43 per cent respectively did not recover). This analysis is based upon cases before 1945 and therefore treated without operation.

The rest of the book (two-thirds) deals with treatment and starts with an admirable review based upon the theme that the results of conservative treatment alone are relatively poor, while stating the importance of conservative treatment as a necessary adjunct. The inadequacies of laminectomy are mentioned, as well as of costo-transversectomy in cases where paraplegia is due to mechanical rather than inflammatory causes. Thus one is led to a considerable discussion of *antero-lateral* decompression and the results in fifty patients so treated: there were thirty-six successes, ten failures and four deaths. Naturally the results were better when more experience of the operation had been obtained and because of this no conclusion statistically can be gained from the effects of

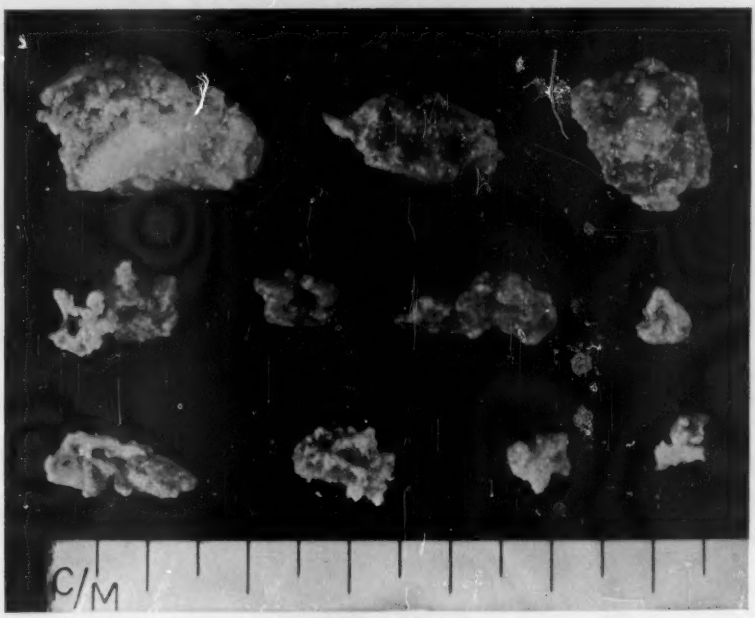


PLATE 9 (*c*)

Eleven sequestra removed at antero-lateral decompression. This mass of sequestra was associated with a bony ridge in the production of paraplegia in a man of thirty-four.
(From *Modern Trends in Orthopaedics*, Second Series, 1956, edited by Sir Harry Platt.)

age of patient, *duration of paralysis* or *site of lesion*. Another ten more recent cases are described by one of the authors from his experience in India, where, in spite of the bad operative risks, the results were strikingly good.

The writer on operation is evidently a great stickler for philological purity. *Rhachiotomy* as a title for opening the spine may be correct by the standards of classical scholarship and the O.E.D., but *Rhachotomy* is normal usage in Greece to-day and in English is comparable to another familiar word of similar root: *cystotomy*. Be that as it may, the writer of this review is much touched by the honour done him in the many references to his operation (*lateral rhachotomy* which has for one of its purposes *anterior* decompression). Nevertheless he finds it hard to recognise some of the extraordinary things he is supposed to do in this operation. It is certainly important to preserve the posterior articular facets if they are not already destroyed by disease. The really important thing is that the compressive agent must be removed from in front of the theca, and therefore all approaches must eventually be anterior.

The neurosurgeons have been more radical: *a*) in the choice of cases for decompression, and *b*) in the larger number of vertebrae exposed. In the latter respect the author of the surgical section follows Professor Norman Dott whose methods he has personally studied. The reason for the former

is that Dott and Alexander, just before 1946, came to the view (quoted by the authors) that the indications for decompression are " no different from those in cord-compression from other causes." Griffiths, Seddon and Roaf disagree with this. Yet it is an important statement: the sort of overstatement that covers the truth. At a time when we were plodding away in fear with occasional decompressions because our teachers were telling us that operative treatment was inadvisable, they had the courage to short-circuit conservatism. The great merit of the present book is that a balanced view of anterior decompression and costotransversectomy is based upon sound study and strong argument. Full quotation is deserving of one significant comment. " We believe that this operation (costo-transversectomy) enlarged to include the evacuation of accessible necrotic material, should be performed in all cases of thoracic tuberculous caries with or without paralysis, if the radiographs show the shadow of an abscess and if the disease is recent." The treatment of necrotic tissue is as important in tuberculosis as in pyogenic osteomyelitis, and for the same reasons.

Laminectomy is shown to have little scope, but why the authors recommend it alone for the neurological complications of lumbar disease is hard to understand when lateral rhachotomy suitably planned is also available in that region. It is also perhaps worth while stressing the importance of the spinal fusion operation in all cases for the stabilisation of the vulnerable area left after decompression.

It is easy to be critical in reading such a work. Putting it together was no easy task and one is filled with admiration and gratitude for the industry that has gone in its production; a most valuable contribution to knowledge and practice.—Norman CAPENER.

HISTOLOGICAL APPEARANCES OF TUMOURS. With a Consideration of their Histogenesis and Certain Aspects of their Clinical Features and Behaviour. By R. Winston EVANS, *T.D.*, B.Sc., M.R.C.S., L.R.C.P., Consultant Pathologist, United Liverpool Hospitals; Lecturer in Clinical Pathology, University of Liverpool. 10×8 in. Pp. xvi+773, with 989 figures. Index. 1956. Edinburgh and London: E. & S. Livingstone Ltd. Price 90s.

This book is an important contribution to that branch of pathological literature which deals with the histological investigation and diagnosis of human tumours. It is written by a broad minded histopathologist of wide experience and mature judgment, who is not only able to describe the minutiae of microscopic structure in clear and attractive language but can make a highly specialised subject interesting to the general reader and useful to the surgeon.

Throughout the thirty-eight chapters of his book Dr Evans lays strong emphasis on the fact that in order to define the genesis of a tumour it is essential to be well acquainted with the normal embryology and histogenesis of its tissue of origin. His preface is headed with this quotation from Nicholson: " Without some knowledge of the development of the part, it is impossible to arrive at a full understanding of its disease." It is a unique feature of this book that in each chapter a clear and concise summary of the development and morphology precedes the description of the tumours arising in the tissue or organ concerned.

A brief examination might leave the impression that the author has devoted undue space to the histology and histogenesis of tumours in which he has a personal interest, and this would constitute a valid criticism of the book if his treatment of common malignant tumours was in any way inadequate. A more detailed examination proves that this is far from the truth, as there are excellent descriptions of the histology of the tumours of all the protective epithelia, the mammary gland and the alimentary tract. It must, however, be agreed that the bulk of the book has been increased by detailed consideration of a number of uncommon tumours whose histogenesis is argued against a background of knowledge and authority. Such chapters deal with tumours of vaso-formative tissue and of the carotid body, the chordomata, the sympathetic system and the endocrine organs. Without these chapters the book would lose a great deal of its merit and the reader would be deprived of the interest engendered by the author's scientific enthusiasm.

The book is exceptional in another direction—it contains no reference to intracranial tumours nor to those of the female generative system. These omissions are deliberate and clearly related to the author's unwillingness, as a general pathologist, to write about subjects which lie within the province of the neuropathologist or the gynaecological pathologist.

We would commend for their clarity and interest the chapters dealing with tumours of cartilage and bone, the synoviomata, myelomata, plasmacytomata and melanomata. The book is profusely illustrated by photomicrographs which are of excellent quality.

It must be emphasised that most of the text is concerned with the histology and histogenesis of tumours; but their behaviour and clinical effects, as well as their biochemical and endocrinological features, are described in outline when they contribute to the investigation of structure and histogenesis and the provision of a histological diagnosis.—Geoffrey HADFIELD.

RECHERCHES SUR LA CONSTITUTION DE L'OS ADULTE. By J. VINCENT, Boursier de l'Institut Interuniversitaire des Sciences Nucléaires. $9\frac{1}{2} \times 6\frac{1}{4}$ in. Pp. 153, with 41 figures. 1955. Bruxelles: Éditions Arscia. Price Belgian francs 200.

In recent years much has been added to the knowledge of bone structure by the application of new techniques. Histochemical methods have supplemented the classical histological studies, and microradiography and autoradiography in particular have shed light on the physiological processes concerned in bone formation and bone resorption. Microradiography consists of the determination

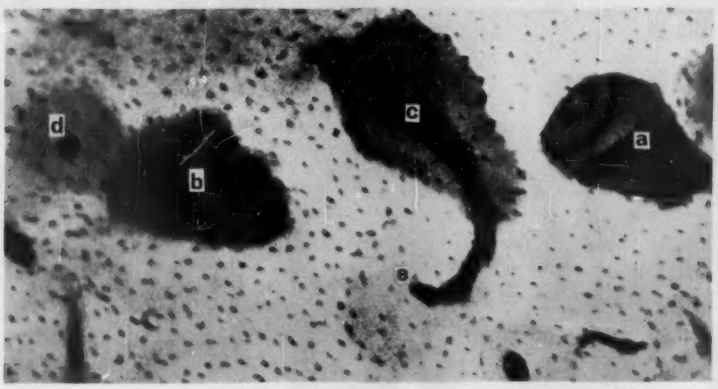


FIG. 2

Microradiograph (×135) of a transverse section of the radial diaphysis of an adult dog. The dark dots are the lacunae containing osteocytes and the varying shades of grey represent different degrees of calcification. *a* and *b* are resorption cavities. *c*, *d* and *e* are completely formed, partially calcified osteones.

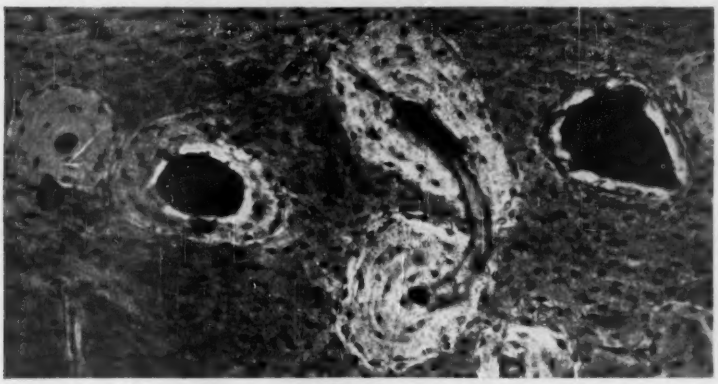


FIG. 3

Comparison of this photomicrograph (×135) of the decalcified unstained section and its microradiograph above shows uncalcified borders of "preosseous tissue" around the resorption cavities.

on a microscopic scale of the x-ray absorption of thin slices of tissue. A thin section of undecalcified bone is placed in contact with a fine-grained photographic emulsion and exposed to soft x-rays. After processing, the radiographic image can be examined under the microscope, and, from the variations in x-ray absorption, inferences can be drawn about the degree of mineralisation in the different areas of the preparation. Engstrom and his colleagues in the Department of Physical Cell Research at the Karolinska Institute in Stockholm have published much work in this field. Autoradiography is the study of the tissue uptake of radioactive substances, as shown by their effect on a photographic emulsion placed in contact with the material to be examined. Work on bone

mineralisation using lead isotopes was carried out by Lomholt as early as 1930, while in recent years the more physiological elements, radiophosphorus P^{32}, and radiocalcium Ca^{45}, have been used for this purpose, and studies of the uptake of C^{14} bicarbonate, and S^{35} sulphate, have also thrown light on the formation of the organic matrix of bone.

The present monograph has the form of a postgraduate dissertation. It is from Professor Lacroix's laboratory at Louvain in Belgium, and correlates histological, microradiographic and autoradiographic studies on the structure of bone. The techniques that have been used are described fully enough to be of use to other workers. The author is chiefly concerned with the bone of the adult dog, and a short section on human adult bone serves chiefly to support the choice of the dog as the experimental animal and to point out a few minor structural differences. The main interest in this work is the light it throws on Haversian remodelling in cortical bone. Dr Vincent has been able to show the steps that occur in the formation of new osteones as they come to replace resorption cavities.

" Pre-osseous " tissue (the " osteoid " tissue of English writers) is formed first. It is uncalcified and so is not demonstrable in microradiographs but is seen in histological preparations. In alcohol-fixed material decalcified by " versene " it stains orthochromatically with toluidin blue. The initially formed tissue shows uptake of radioactive sulphur, but not of radioactive calcium. Later, this " pre-osseous " tissue becomes calcified, rapidly acquiring about two-thirds of its ultimate content of bone salt. It is then apparent in microradiographs, and shows active uptake of radioactive calcium. The calcified tissue stains metachromatically with toluidin blue. The final completion of the mineralisation of the osteone is a slow process.

By serial studies after the administration of radioactive sulphur Dr Vincent has been able to estimate that in the adult dog the deposition of an osteone takes about six weeks but its complete calcification takes more than twelve weeks. He has found also that Haversian remodelling is an intermittent process and may cease temporarily either locally or in the skeleton as a whole. In spongy bone interpretation is more difficult, but here also there is evidence of remodelling. This occurs particularly in the metaphysis and resembles that seen in cortical bone.

Finally Dr Vincent discusses his results in relation to the general background of bone physiology and biochemistry, and suggests further lines of inquiry which appear capable of solution by the methods of study outlined.

The work is effectively illustrated by sets of comparable photomicrographs, microradiographs and autoradiographs, which add much to the clarity of the exposition. It is unfortunate that these illustrations are grouped together at the end of the book and not placed at the points in the text where they are discussed. There is an excellent bibliography.—Mary CATTO.

MANAGEMENT OF LIFE-THREATENING POLIOMYELITIS. Copenhagen, 1952–1956. Edited by H. C. A. LASSEN, M.D., Professor of Epidemiology, University of Copenhagen; Chief Physician, Department of Communicable Diseases, Blegdamshospitalet, Copenhagen; with twenty-one other contributors. $8\frac{3}{4} \times 5\frac{3}{4}$ in. Pp. xi+179, with 55 figures and 32 tables. 1956. Edinburgh and London: E. & S. Livingstone Ltd. Price 22s. 6d.

This book reports an epidemic of poliomyelitis which was in many respects the worst on record. The incidence in Copenhagen reached 105 paralytic and 153 non-paralytic patients per 100,000 population. At the peak there were 320 hospital admissions in a week. Of a total of 5,675 patients, 345 had severe paralysis of respiratory muscles or of swallowing and of these 42 per cent died. Of the 345, twelve had failure of swallowing alone, 254 respiratory muscle failure and no less than 79 had respiratory and pharyngo-laryngeal paralysis. The Danes had to treat these desperately ill patients with no hope of providing negative pressure cabinet respirators for more than a negligible fraction; indeed, this group of patients included an unheard of proportion for whom that type of aid would have been ineffective. A team of physicians, anaesthetists and laryngologists therefore improvised a method and recruited assistants. This team aided by neurologists, epidemiologists, biochemists and pathologists has now given us its results.

A method providing adequate ventilation had to be devised with which patency of the air passages could also be maintained. Postural drainage and pharyngeal suction had been proved completely inadequate for patients with secretions in the tracheobronchial tree resulting from failure of swallowing or from anoxic and hypercapnic hypersecretion. The method had also to allow both adequate oxygenation and carbon dioxide removal. The need was met by tracheotomy and insertion of an inflatable cuffed anaesthetic tube. Positive pressure ventilation was achieved by the manual compression of a rubber bag attached to this tube; the circuit included both a soda-lime carbon dioxide absorber and a supply of equal parts of oxygen and nitrogen. Frequent aspiration of the trachea and main bronchi was possible through the tracheotomy. Teams of helpers worked in shifts with this apparatus

throughout the epidemic. It is clear that experience had still to be dearly gained: of the first thirty-one patients subjected to tracheotomy over 80 per cent died. The total mortality, however, of 268 patients so treated was little more than 30 per cent.

A flow of at least five litres a minute was used with respiratory rates varying between fifteen and thirty a minute according to age. Broadly speaking, all "wet" patients (that is, those with accumulated secretions, whether the paralysis was "spinal" or "bulbar" or mixed in origin) were treated by tracheotomy and positive-pressure ventilation. Only "dry" pure "spinal" patients were treated in cabinet respirators. Tracheotomy was performed under a general anaesthetic after laryngeal intubation, if possible before the development of anoxia. Many patients, however, were admitted in severe asphyxia.

There is discussion of the best and least damaging technique for a tracheotomy that may be required for weeks. The principles of lung physiotherapy with and after closure of tracheotomy had to be learned. Decannulation (an unpleasing word) was attempted as soon as positive-pressure respiration could be dispensed with, swallowing was normal and secretions could be cleared by assisted coughing only.

The team had two groups of problems remaining after deciding upon the method of ventilation. Observation of the disease itself both in its primary manifestations and in its complications was still required. This included the differentiation of the symptoms of anoxia and carbon dioxide retention; the treatment of shock and hypotension, especially when the relief of carbon dioxide retention had removed the hypertension that this produces; the differentiation of encephalitis from symptoms and signs that they call "cerebralia," *i.e.*, nervous system damage produced by anoxia, hypercapnia, hyperpyrexia, uraemia, etc. Secondly, control of the method of treatment had to be learned and its complications avoided. Crust formation in the air passages was relieved by a humidifier in the circuit. Analyses of blood and expired air were necessary if hypoventilation and hyperventilation were to be avoided. Shock required treatment with care to avoid pulmonary oedema from intravenous fluid overload. A correct electrolyte balance by means of nasal or intravenous feeding had to be maintained, often with the additional complication of the high blood non-protein-nitrogen that follows massive muscle degeneration. Constant co-operation with the laboratory was an absolute necessity. Many of the problems were not new nor first answered in Denmark but they were new to Denmark. The improvement in mortality rate as the team profited by experience has been noted already.

Chapters on the laboratory control of gas exchange, electro-cardiographic changes in poliomyelitis, the biochemical background of renal calculus formation in the severely paralysed and a detailed group of autopsy findings all show the care with which the team who have now produced this book collected and analysed the results of their experience.

No book can give more than a notion of how to treat severe respiratory poliomyelitis: personal experience alone can realise the problems. But this work will at least forearm those prepared to reconnoitre a position in which we might yet find ourselves. If our initial mortality rate were then less than 80 per cent the book would have fulfilled its purpose.

The translation is idiomatic, the style succinct but readable. Tables, diagrams and clear photographs have been used freely. There is a printer's error in Table VI (*b*) but the standard of care in production of the volume has obviously been high. Its 179 pages are the valuable fruit of first-hand experience.—F. Harwood STEVENSON.

POLIOMYELITIS: Papers and Discussions Presented at the Third International Poliomyelitis Conference. Compiled and edited for the International Poliomyelitis Congress. $10\frac{1}{4} \times 7\frac{1}{2}$ in. Pp. xxiv+567, with 442 figures. Index. 1955. Philadelphia and Montreal: J. B. Lippincott Co. London: Pitman Medical Publishing Co. Ltd. Price 60s.

As in the previous two volumes this text gives a full report of all the transactions of the relevant conference, on this occasion in Rome in 1954. The first day was devoted to the social aspects of poliomyelitis, and the best remarks were made by Dr S. M. Clemmesen on the devastating effect of acquiring a cripple mentality, especially in children, and the absolute need for employment of the disabled person amongst normal people: he also touched on the problem of deciding whether to break education for a period of one or two years for correction of spinal deformities.

On the second day the acute medical care in poliomyelitis was debated. Dr A. J. Rhodes reviewed the clinical and differential diagnosis of the disease and stressed the difficulties that have arisen from newly discovered poliomyelitis-like viruses and illnesses. Dr W. Ritchie Russell brought forward no new method of treating the acute phase of the disease, but he insisted on complete physiological inactivity and fortunately did not consider diagnostic lumbar puncture—a harmful measure; he uses no form of immobilisation, and gives passive movements in the care of muscles

and posture. In the reviewer's opinion this line of treatment is rational and preferable and must come to be accepted by orthopaedic surgeons. Dr H. L. Hodes gave a logical procedure for the treatment of respiratory difficulty, but there was much discussion especially by the proponents of positive ventilation.

The third day proved to be the best and most stimulating of the conference, even though the Francis report had not been published then and therefore its findings were not known. After Dr H. Muench had spoken on the influence of passive immunisation on the incidence of poliomyelitis and Dr J. E. Salk had given his paper on studies with non-infectious poliomyelitis virus vaccines, Dr Albert Sabin spoke on avirulent viruses for immunisation against poliomyelitis, and left most of the audience hoping that an effective live vaccine will eventually come to pass. Dr J. F. Enders reported further developments in tissue culture and the paper received very full discussion.

The fourth day was devoted to orthopaedics and physical medicine, and it was a disappointing day. Dr P. C. Colonna contented himself with a review of the orthopaedic surgery practised in the United States for poliomyelitis, and Dr C. Marino-Zuco reviewed operations for stabilising joints. The three papers on physical medicine added nothing to what is normally practised, and aired not a few hoary shibboleths. The panel discussion on orthopaedics was of interest but showed no dominant line of treatment.

The last day was devoted to the consideration of trends in poliomyelitis, and wound up with summaries of the papers given on previous days. Apart from the work on immunisation the reviewer feels that much of the time of the conference had been spent in scraping the bottom of the barrel. The scientific exhibits were of the accustomed high standard.

On the whole this third volume will prove rather a disappointment to any reader who is already familiar with the first and second volumes. It is not recommended at all for the orthopaedic surgeon who does not stray from the narrow concept of his speciality and therefore regards poliomyelitis as a disease of occasional surgical interest.—John M. P. CLARK.

THE SPINE. A Radiological Text and Atlas. By Bernard S. EPSTEIN, M.D., Chief, Department of Radiology, The Long Island Jewish Hospital, New York. $10\frac{1}{2} \times 7\frac{1}{2}$ in. Pp. 539, with 331 figures. Index. 1955. London: Henry Kimpton. Price £6.

The Spine is a radiological text-book. In it Dr Epstein has attempted to put together statements of fact and opinion concerning every abnormality that might be encountered in the spine radiologically. This, in itself an immense task, cannot have been made easier by the need for thumbnail sketches of the known clinical and pathological data of every disease process encountered.

In one sense radiology can be regarded as a means of providing "macroscopic appearances" in the living subject. Unlike morbid anatomy, it is not a basic medical science and its points of contact with clinical medicine and pathology are almost impossible to limit or define. The author has taken the view that as much clinical and pathological material as it was possible to compress into a book of this size should be made available. The outcome is a text-book which, while giving due prominence to radiology, also manages to provide an extensive clinical background to the conditions described.

The opening chapters deal with the normal spine, its embryology, function and architecture. Sections are then devoted to a very full account of congenital and developmental disorders, the inflammatory, degenerative and noxious diseases, neoplasms, trauma, the intervertebral discs, the spinal cord and its meninges, and discussions of the haematopoietic, collagen and reticulo-endothelial systems.

The subject matter is vast in scope and complexity and one must have the greatest admiration for the author for the thorough manner in which he has performed his task. It is probable that individual specialists will find material for disagreement where the author, in attempting to cover the clinical aspects of a particular problem, may have misplaced his emphasis. But throughout there occur small symposiums on many subjects which by reason of the simple collection of recorded fact are highly stimulating. For example, in the discussion on disc degeneration the condition of transitory disc calcification associated with localised pain, originally reported by Brailsford, is examined and the literature is surveyed. Dr Epstein's long experience in the field of myelography and his intimate knowledge of its literature is well displayed in a comprehensive section of his book.

In a work of this scope some points of criticism are inevitable. The work might gain in value if the various sections could be subdivided, so that the radiological appearances were specifically described and separated from the clinical and pathological discussions. In particular, a deliberate attempt in each section to tackle the problem of differential diagnosis would be of enormous value.

Too often the text comprises a consecutive series of references and extracted statements and lacks the summary which gives cohesion. One sometimes felt that the author's opinion on a series of quotations from the literature would have been of the greatest help to the radiologist making a rapid reference. It is evident that this defect, if defect it is, springs from the necessity for condensation, for it is absent from the sections on anatomy and embryology and from the long and exhaustive discussions on the spinal cord.

There are over 700 separate illustrations. The great majority are admirably suited to their purpose, but at least twenty are unsatisfactory. The term diaphysial aclasis is given as an alternative, among others, to dyschondroplasia, but is not given as an alternative to hereditary multiple exostosis. In the description of fibrous dysplasia, in which specific spinal changes are thought not to occur, there follows the description of spinal changes in an eighteen-year-old boy who had suffered repeated fractures. These changes, consisting primarily of " a loss of the normal trabecular markings," could, from the description, have been due to prolonged recumbency or other cause; and it would be undesirable to ascribe them to fibrous dysplasia without fuller discussion. The vexed question of vertebra plana (Calvé's disease) is not eased by the use of the term vertebra plana as specific to one condition only during the early part of the discussion and then to other conditions produced by destructive processes. Three illustrations of Calvé's disease (vertebra plana) are given. The first would appear to represent osteochondrodystrophy, and the others spinal tuberculosis in a child. These illustrations were taken from an article by Sundt, who described two cases of Calvé's disease and included these three illustrations to demonstrate other causes of vertebral body collapse. In the section dealing with ankylosing spondylitis, no attempt is made to define this as a clinical entity when considered in the context of general rheumatoid arthritis. These are minor criticisms in relation to the breadth and compass of this book, which will in its succeeding editions become, I am sure, an established work of reference and a necessity in every radiological library.—L. S. CARSTAIRS.

RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE KNEE. A Standard of Reference. By S. Idell PYLE, Ph.D., and Normand L. HOERR, Ph.D., M.D. From the Department of Anatomy, Western Reserve University School of Medicine, Cleveland, Ohio. 11¼×9 in. Pp. viii+82, with 29 plates. 1955. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications. Price 31s.

This is the second radiographic atlas depicting skeletal development and follows the earlier publication of an atlas devoted to the development of the hand and wrist. This volume like the former is based on work carried out at the Brush Foundation, which is affiliated with the School of Medicine of Western Reserve University, Cleveland, Ohio.

It is intended that this atlas shall portray skeletal development under the best conditions of health, and the authors are careful to point out that the subjects have been carefully selected, as healthy, well nourished children with good medical and environmental histories: it was considered undesirable to lower the general average by including a number of children with unsatisfactory nutrition or general health, as would happen in an indiscriminate cross section.

The examinations from which the standard radiographs have been selected were made four times during the first year of growth, at six monthly intervals thereafter up to the age of five years and at yearly intervals thereafter until complete maturity. The radiographs were collected during the years 1928 to 1942.

One problem that confronted the authors at the outset was the difficulty of selecting a standard for each age group where, even among healthy children, the normal rate of development varied considerably. The magnitude of the material offered the solution. One hundred knee radiographs of each age group were arranged in order of maturation, the fiftieth film being taken as the characteristic for the age. As an indication of how wide the range is, the authors illustrate the most advanced knee radiograph of a boy of six against the middle range of a boy of eight and the least advanced radiograph of a boy of ten; these radiographs are almost identical.

Because a girl's skeleton matures more rapidly than a boy's it was necessary to differentiate the sexes in the atlas. However, the authors have avoided duplicating radiographs by attaching a male skeletal age and a female skeletal age to each standard radiograph; these differ in the middle ranges of development by about one year.

As criteria of maturity the authors have selected what they call " maturity indicators "; these are features of shape, size, density of the epiphyses and ends of the diaphyses which have been found to be reasonably constant. It is surprising, in view of the excellent general format of this volume, that the standard of reproduction of the radiographs has not been somewhat higher and that in some few cases a radiograph of indifferent quality has been selected when the wealth of material

would be expected to offer a better specimen. In general, however, the details described in the text of the various maturity indicators are not unduly obscured by lack of quality.

This volume, along with that depicting the hand, will make a very useful standard of reference for assessing skeletal maturity in the diagnosis, and control during treatment, of nutritional and endocrine disorders.—A. M. RACKOW.

ROENTGEN EXAMINATION OF THE PROXIMAL FEMUR END IN CHILDREN AND ADOLESCENTS. A standardized technique also suitable for determination of the collum-, anteversion-, and epiphyseal angles. A study of slipped epiphysis and coxa plana. By Lars BILLING. $9\frac{1}{2} \times 7\frac{1}{4}$ in. Pp. 80, with 23 figures, 4 tables and 4 nomograms. 1954. Stockholm: Acta Radiologica, Supplementum 110. Price Swed. kr. 25.50.

In meticulous mathematical detail the author describes the best way to make a roentgen examination of the upper end of the femur. Special attention is directed to the importance of avoiding the shortening effect common to many routine examinations. The knowledge thus gained is applied with infinite care and considerable ingenuity to the examination of patients with slipping of the upper femoral epiphysis and to the examination of coxa plana. A method of " nailing in situ " is described, together with very clear definition of the exact radiographic technique. The manner in which slipping occurs and the possible causes are discussed. The publication abounds in excellent illustrations, very clear diagrams, graphs and tables. It ought to prove a great help to anyone responsible for treating patients with abnormalities of the upper femoral epiphysis, always provided that the orthopaedic surgeon can appreciate the stereo-geometrical calculations and the nomographic information.—Bryan MCFARLAND.

DIE CHIRURGIE DER PERIPHEREN NERVEN. By Henry NIGST. $9\frac{1}{2} \times 7$ in. Pp. viii+196, with 104 figures. Index. 1955. Stuttgart: Georg Thieme Verlag. Price 55s. 6d.

This book is an excellent monograph on peripheral nerve injuries, and will I believe be of great value to German surgeons. Its contents are based upon the author's considerable experience, most of which appears to have been gained in this country whilst he was working with Mr H. J. Seddon. The book contains almost the same material as the recent publication of the Medical Research Council on Peripheral Nerve Injuries, which to British surgeons is likely to be very much more convenient. The book is excellently produced and very well illustrated. The chapters on the individual nerves are excellent, the diagnosis, treatment and reconstructive procedures being fully discussed. This section would undoubtedly be of value to surgeons in this country.—F. W. HOLDSWORTH.

BOOKS RECEIVED

These books are acknowledged with grateful thanks. Selections will be made for review as space permits and in accordance with their interest for our readers.

LIVING BONE IN HEALTH AND DISEASE. By Irvin STEIN, A.B., M.D., F.A.C.S., F.I.C.S., Raymond O. STEIN, A.B., M.D., F.I.C.S., and Martin L. BELLER, A.B., M.D. 1955. London: Pitman Medical Publishing Co. Ltd.

LA RIEDUCAZIONE MOTORIA DELLE PARALISI CEREBRALI INFANTILI. By A. Colli GRISONI. 1955. Bologna: Editore Liginio Cappelli.

THE PATHOGENESIS OF POLIOMYELITIS. By Harold K. FABER, M.D. 1955. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications.

THE BACK AND ITS DISK SYNDROMES. By Philip LEWIN, M.D., F.A.C.S., F.I.C.S. Second edition. 1955. London: Henry Kimpton.

PATOLOGIA E CLINICA DELL'ERNIA POSTERIORE DEL DISCO INTERVERTEBRALE. By Gianfranco FINESCHI. 1955. Firenze: Edizioni Scientifiche Istituto Ortopedico Toscano.

LOW BACK PAIN IN INDUSTRY. By Henry H. KESSLER, M.D., Ph.D. 1956. New York: Commerce and Industry Association of New York Inc.

PERIPHERAL VASCULAR DISORDERS. Edited by Peter MARTIN, V.R.D., M.Chir., F.R.C.S.Ed., R. Beverley LYNN, M.D., F.R.C.S., J. Henry DIBLE, M.B., LL.D., F.R.C.P., and Ian AIRD, Ch.M., F.R.C.S., with five other contributors. 1956. Edinburgh and London: E. & S. Livingstone Ltd.

FONCTIONS ET BILAN ARTICULAIRES. By Ch. ROCHER and A. RIGAUD. 1956. Paris: Masson et Cie, Editeurs.

PHYSIOTHERAPY IN PARAPLEGIA. By Elvira P. G. HOBSON, F.C.S.P. 1956. London: J. & A. Churchill Ltd.

CAMPBELL'S OPERATIVE ORTHOPAEDICS. Editor, J. S. SPEED, M.D., Associate Editor, Robert A. KNIGHT, M.D. Third edition. Volumes I and II. 1956. London: Henry Kimpton.

POSTURAL AND RELAXATION TRAINING IN PHYSIOTHERAPY AND PHYSICAL EDUCATION. By John H. C. COLSON, F.C.S.P., M.S.R.G., M.A.O.T. 1956. London: William Heinemann Medical Books Ltd.

LIFE OF SIR JOHN BLAND-SUTTON, BT. By W. R. BETT, M.R.C.S.Eng. 1956. Edinburgh and London: E. & S. Livingstone Ltd.

JOINT LIGAMENT RELAXATION TREATED BY FIBRO-OSSEOUS PROLIFERATION. By George Stuart HACKETT, M.D., F.A.C.S. 1956. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications.

THE BIOCHEMISTRY AND PHYSIOLOGY OF BONE. Edited by Geoffrey H. BOURNE, with twenty-seven other contributors. 1956. New York: Academic Press Inc., London: Academic Books Ltd.

THE PATHOLOGY AND SURGERY OF THE VEINS OF THE LOWER LIMB. By Harold DODD, Ch.M., F.R.C.S., and Frank B. COCKETT, M.S., F.R.C.S. 1956. Edinburgh and London: E. & S. Livingstone Ltd.

BORDERLANDS OF THE NORMAL AND EARLY PATHOLOGIC IN SKELETAL ROENTGENOLOGY. By Alban KÖHLER. Tenth edition completely revised with reference to illustrations and to text by E. A. ZIMMER; English translation arranged and edited by James T. CASE, M.D., D.M.R.E.(Cambridge). 1956. New York and London: Grune & Stratton Inc.

THE LIFE OF HUGH OWEN THOMAS. By David Le VAY, M.S.(Lond.), F.R.C.S.(Eng.). 1956. Edinburgh and London: E. & S. Livingstone Ltd.

BONE STRUCTURE AND METABOLISM. Editors, G. E. W. WOLSTENHOLME, *O.B.E.*, M.A., M.B., B.Ch., and Cecilia M. O'CONNOR, B.Sc. 1956. London: J. & A. Churchill Ltd.

THE SPINE. By Lee A. HADLEY, M.D. 1956. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications.

SURGERY OF THE HAND. By Sterling BUNNELL, M.D. Third edition. 1956. London: Pitman Medical Publishing Co. Ltd.

ORTHOPAEDIC NURSING. By Mary POWELL, S.R.N., M.C.S.P. Second edition. Edinburgh and London: E. & S. Livingstone Ltd.

PYE'S SURGICAL HANDICRAFT. Edited by Hamilton BAILEY, F.R.C.S., F.A.C.S., F.I.C.S., F.R.S.E. Seventeenth edition. 1956. Bristol: John Wright & Sons Ltd.

ANATOMICAL TECHNIQUES. By D. H. TOMPSETT, B.Sc., Ph.D. 1956. Edinburgh and London: E. & S. Livingstone Ltd.

THE TREATMENT OF FRACTURES. By Lorenz BÖHLER, M.D. Volume I. Translated from the Thirteenth German edition by Hans TRETTER, Helen B. LUCHINI, Frank KREUZ, Otto A. RUSSE and Robert G. B. BJORNSON. 1956. New York and London: Grune & Stratton.

ACKNOWLEDGMENTS

We acknowledge with thanks receipt of:

Acta Chirurgica Scandinavica, and Supplements
Acta Ortopedica-Traumatologica Iberica
Annals of the Royal College of Surgeons of England
Archives of Surgery
Boletin de la Sociedad de Cirugia del Uruguay
British Journal of Surgery
British Medical Bulletin
Journal of Neurology, Neurosurgery and Psychiatry
Journal of the American Medical Association
Journal of the Royal College of Surgeons of Edinburgh
Lancet
Ortopedia e Traumatologia dell'Apparato Motore
Radiology
Revista de Ortopedia y Traumatologia
Revue de Chirurgie Orthopédique
Surgery, Gynecology and Obstetrics
Zeitschrift für Orthopädie und ihre Grenzgebiete

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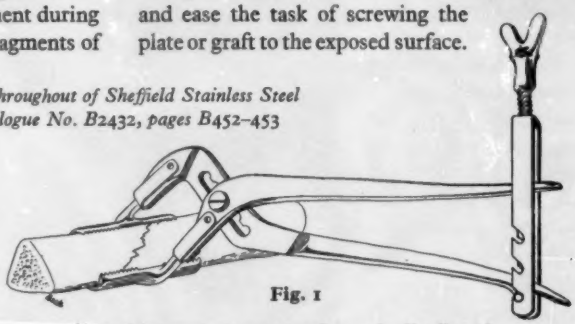

Fig. 1

Swivel jaws ensure pressure is evenly distributed, and fragments which taper or are of different diameters are securely held.

Fig. 2
Hooked jaws used to grip a fractured patella.

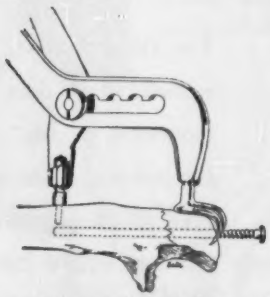

Fig. 3
Hooked jaw and peg used to grip fractured olecranon (also medial malleolus). ¼" diam. hole drilled in shaft of ulna or tibia acts as fixation point.

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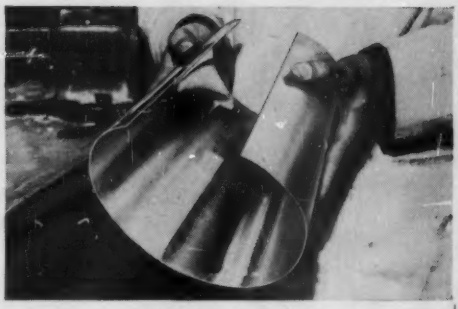

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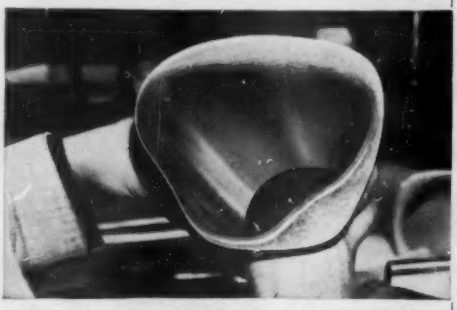

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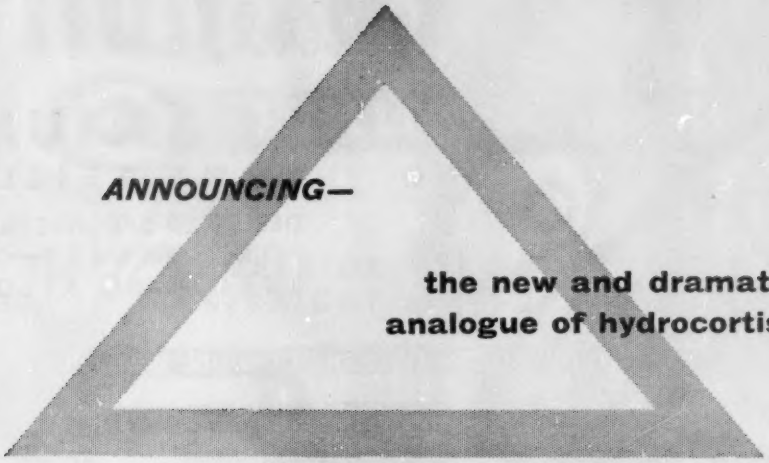

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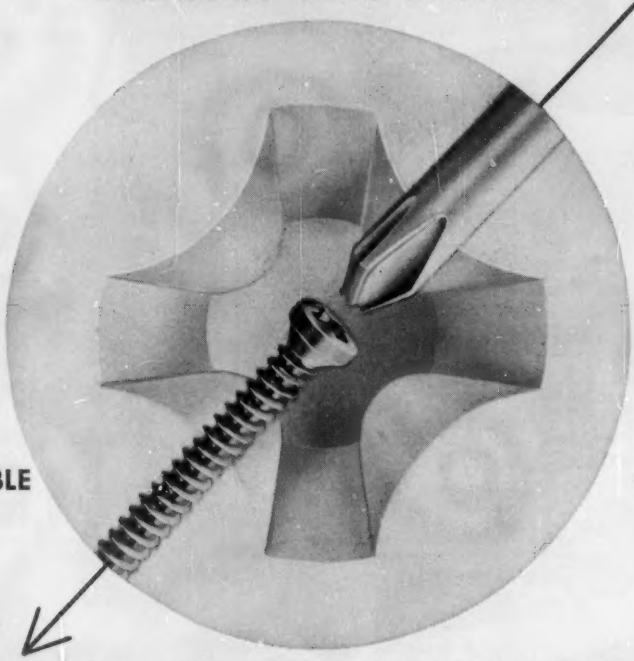

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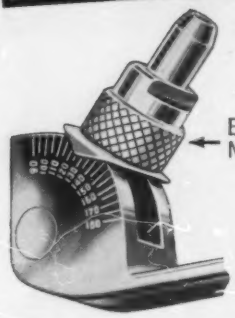

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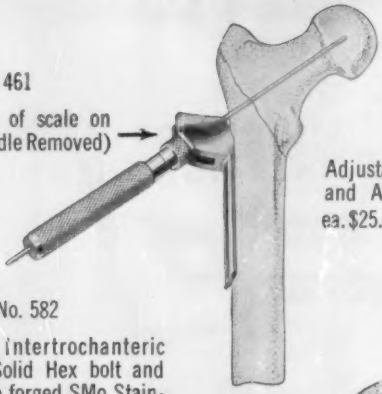

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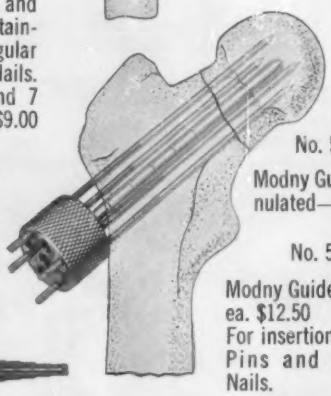

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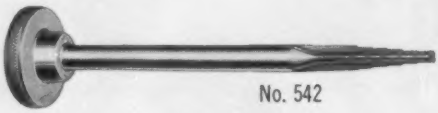

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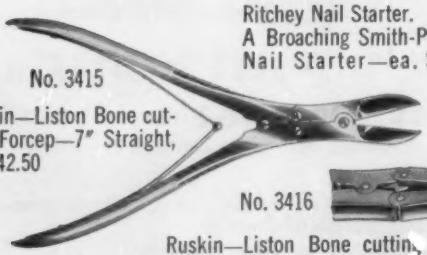

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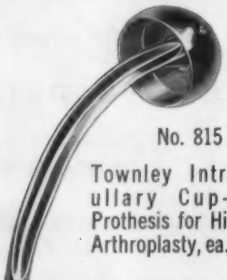

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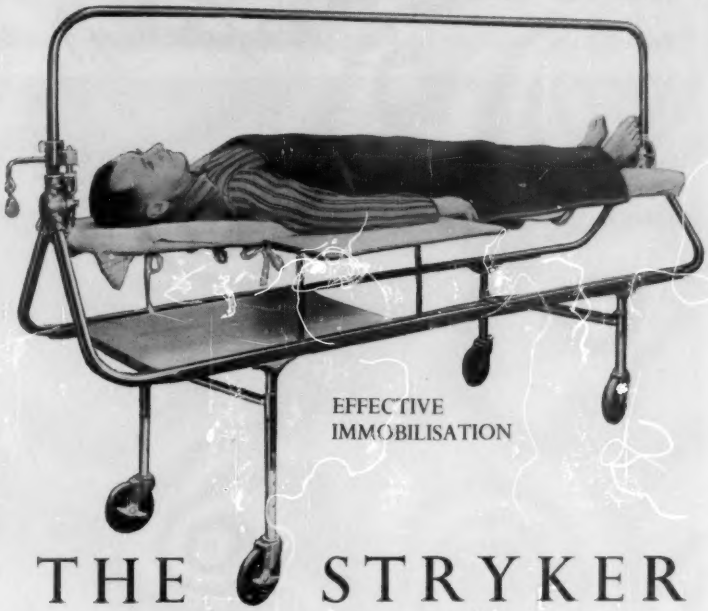

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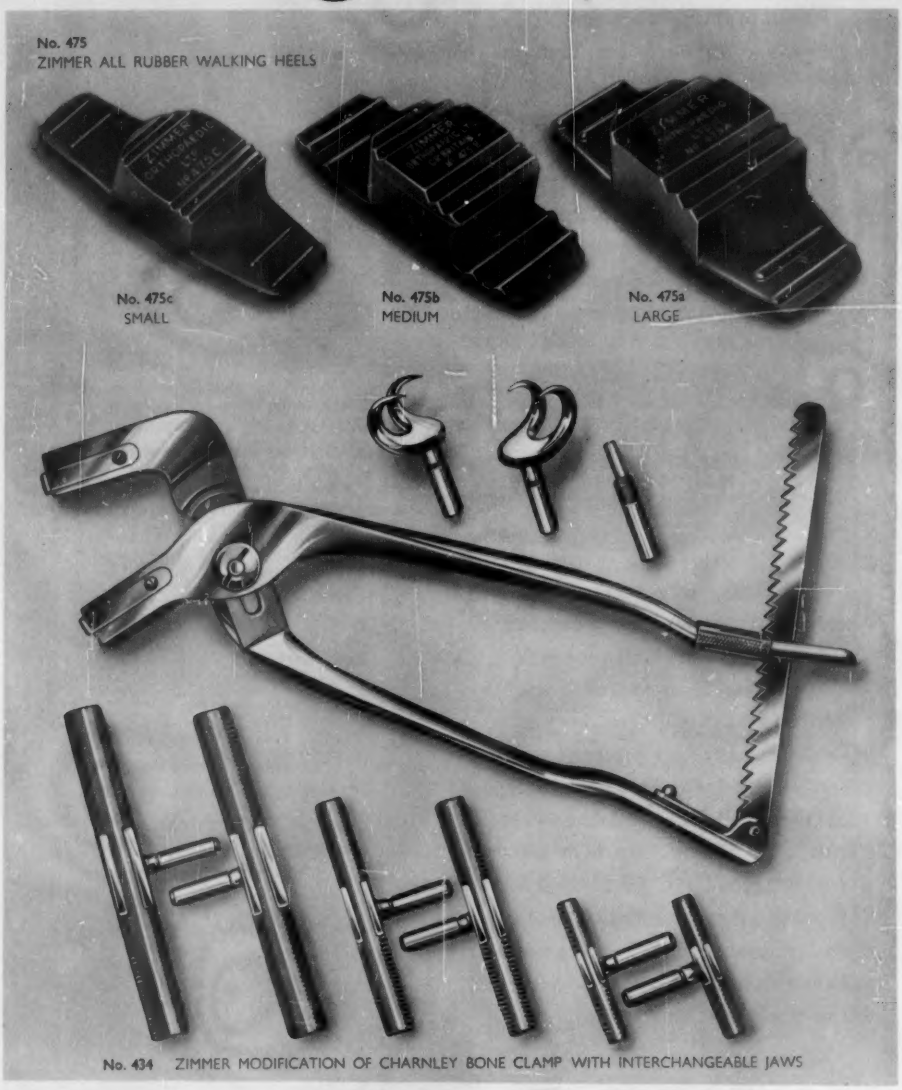

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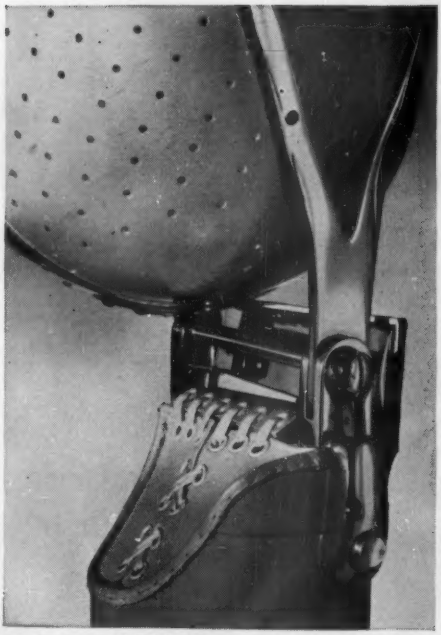

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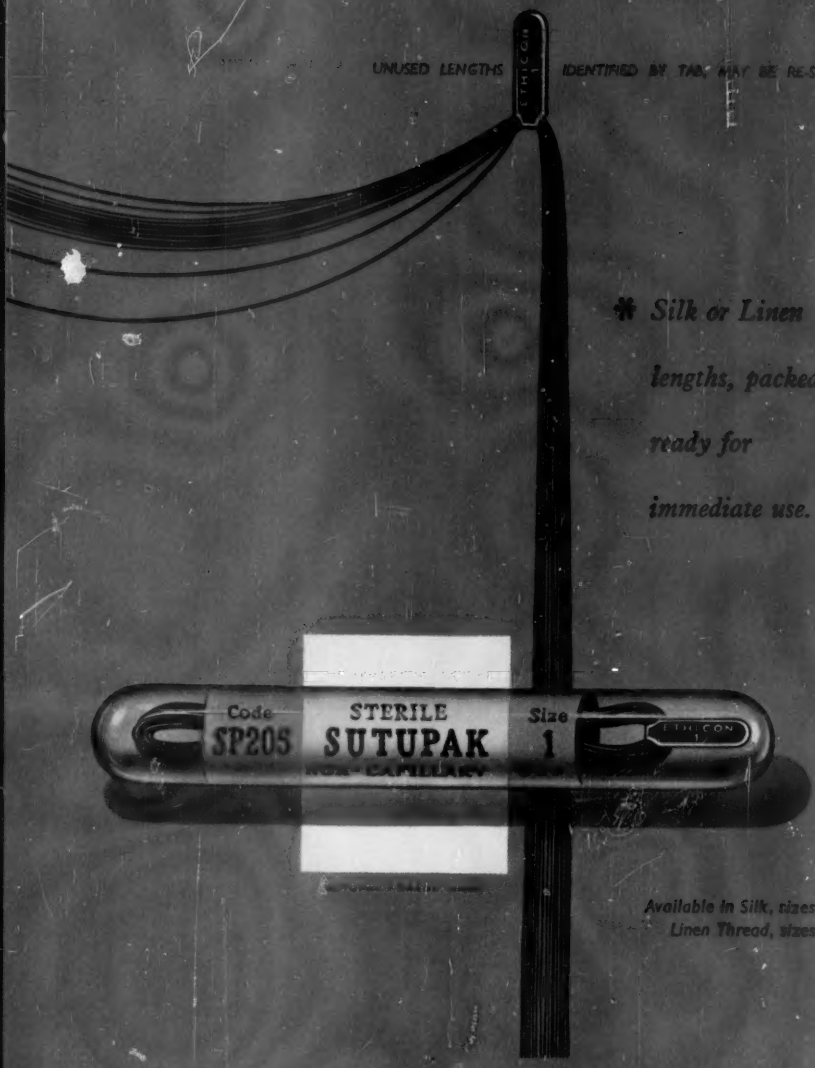

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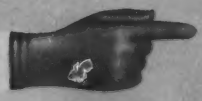

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